SEWAGE AND INDUSTRIAL WASTES

JOURNAL of the FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

Special Features

1958 Literature Review, Part I—Research Committee
Analytical Methods, Sewage

Sewer Rates—Osborne

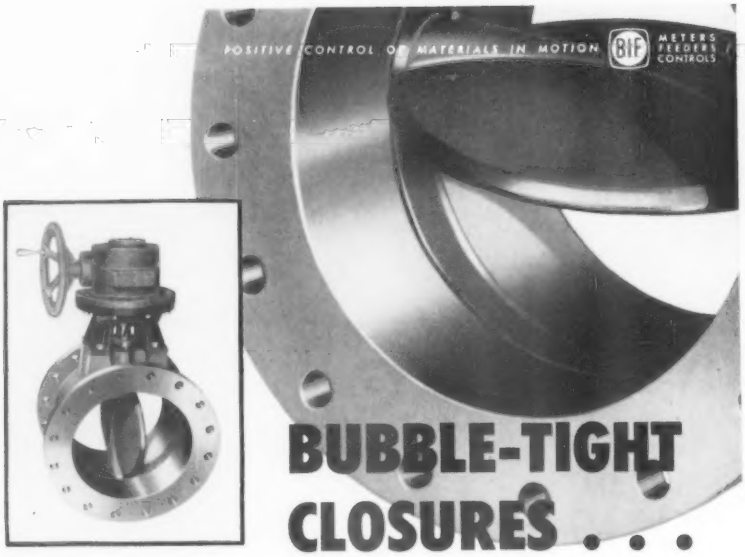
Insecticide Toxicity to Fish—Weiss

Zirconium Wastes—Palange et al.

Syndet Research—McKinney and Symons

Operator Certification—Voluntary and Mandatory

MAY 1959—VOL. 31, No. 5



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Journal of the Federation of Sewage and Industrial Wastes Associations

Volume 31 **May 1959** **Number 5**

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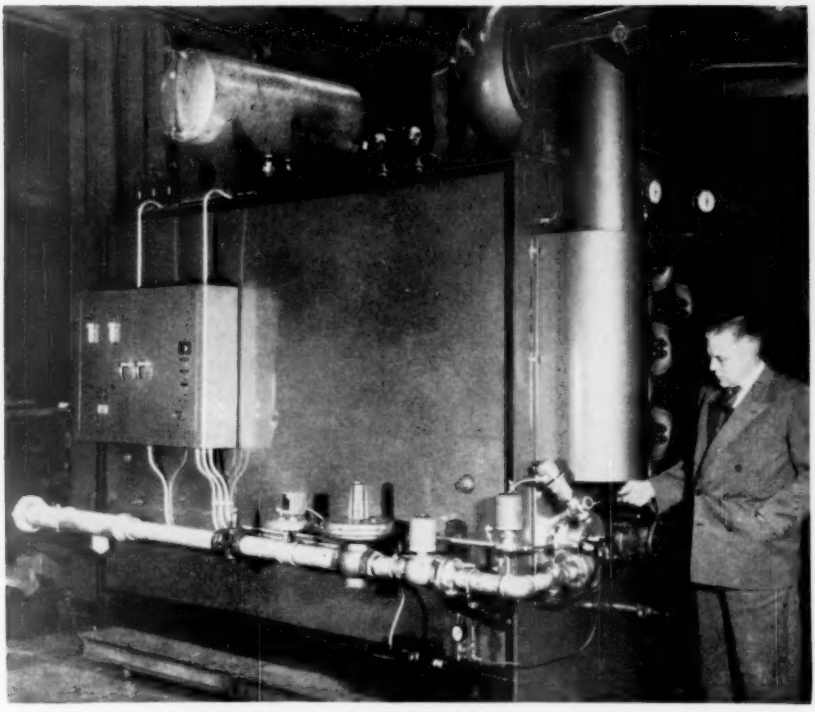

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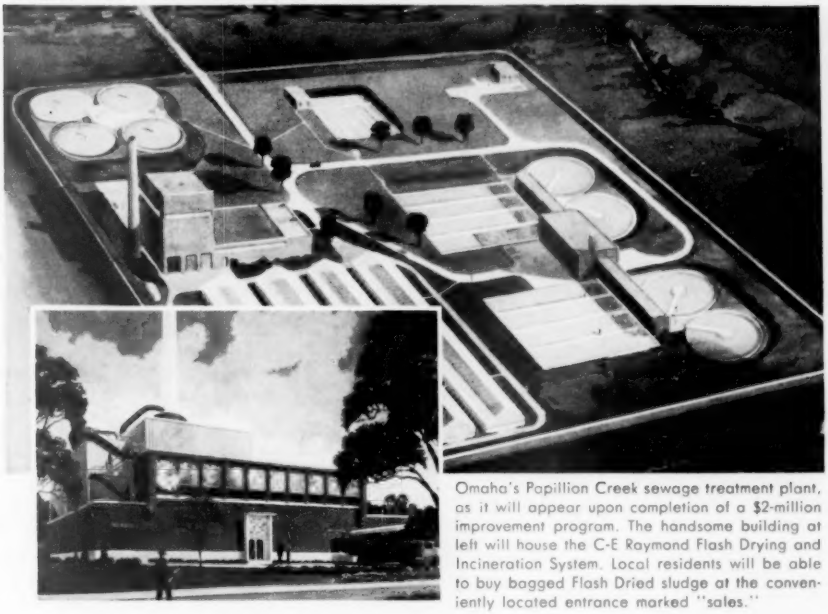

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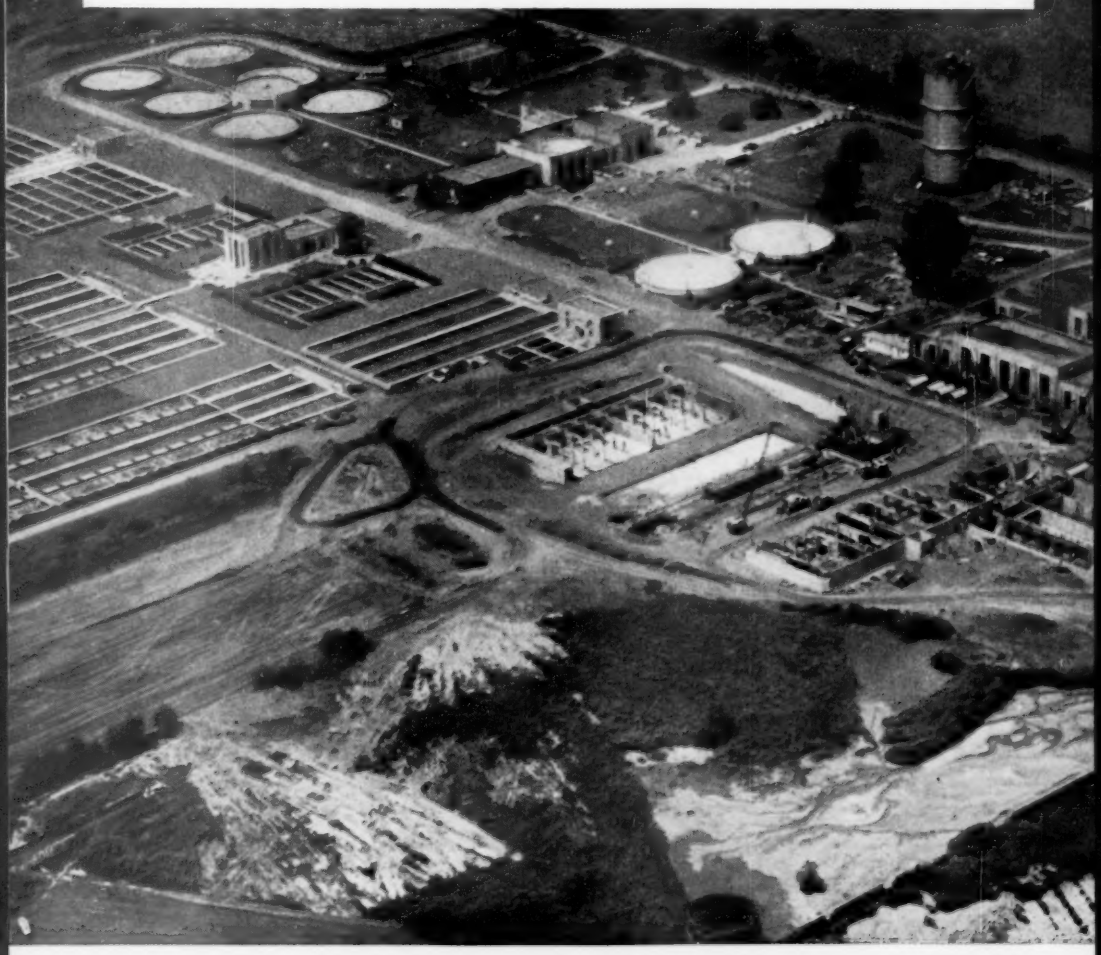

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Association	*Place*	*Time*
Michigan Sewage and Industrial Wastes Assn.	Wenonah Hotel Bay City, Mich.	May 11–13, 1959
New England Sewage and Industrial Wastes Assn. (*Spring Meeting*)	Exeter Inn Exeter, N. H.	May 13–14, 1959
Alabama Water and Sewage Assn.	University of Alabama University, Ala.	June 3–5, 1959
Maryland-Delaware Water and Sewage Assn.	Commander Hotel Ocean City, Md.	June 3–5, 1959
New York Sewage and Industrial Wastes Assn. (*Spring Meeting*)	Saranac Inn Upper Saranac Lake, N. Y.	June 8–9, 1959
Ohio Sewage and Industrial Wastes Treatment Conf.	Netherlands Plaza Cincinnati, Ohio	June 17–19, 1959
Iowa Sewage and Industrial Wastes Assn.	Roosevelt Hotel Cedar Rapids, Iowa	June 17–19, 1959
Institute of Sewage Purification	Bournemouth, England	June 23–26, 1959
Central States Sewage and Industrial Wastes Assn.	Pick Nicollet Hotel Minneapolis, Minn.	June 24–26, 1959
Pennsylvania Sewage and Industrial Wastes Assn.	Pennsylvania State Univ. University Park, Pa.	Aug. 12–14, 1959
South Dakota Water and Sewage Works Conf.	Marvin Hughitt Hotel Huron, S. Dak.	Sept. 2–4, 1959

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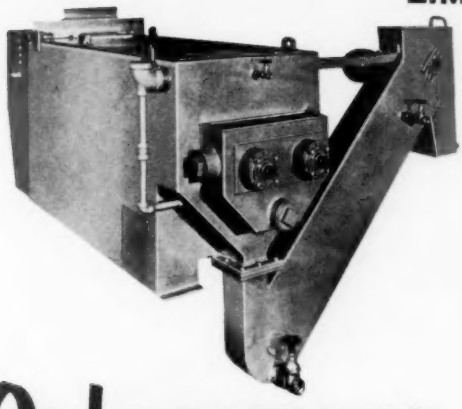

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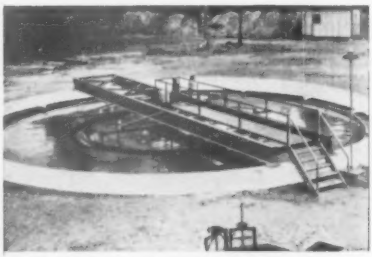
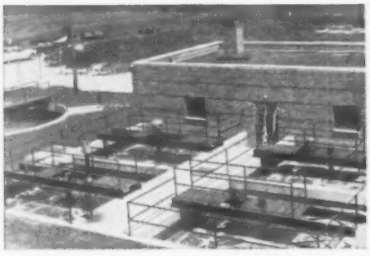
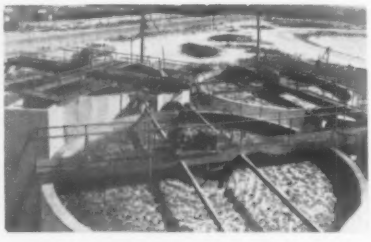


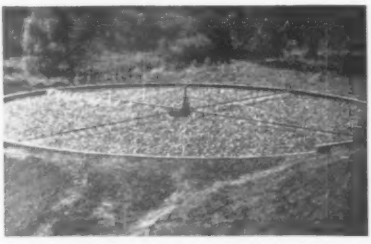
. . **SPIRAFLO CLARIFIER** for both primary and final clarification of domestic and process wastes. A clarifier of radically different design, the Spiraflo offers complete settleable solids removal; greater removal of finely divided particles; positive grease, scum oil removal; uniform velocity throughout tank; and straight wall design which reduces construction costs.



. . the **CAVITATOR**, a newly developed Yeomans unit for low cost treatment of both domestic sewage and industrial wastes. Perfectly suited for small communities, subdivisions, motels, resorts, schools and industrial plants, the Cavitator has excellent purification efficiency, extremely high oxygen transfer efficiency, and extremely low air requirements per pound of B.O.D. removed.



. . the **HI-CONE**, the most important development in the surface aeration process of activated sludge treatment in the last 30 years. The Hi-Cone offers much greater circulation, and can handle substantially more sewage with no increase in power consumption per MG treated. Maintenance costs are minimized because nothing can clog.



. . **YEOMANS ROTARY DISTRIBUTORS** (both standard rate and high capacity). Standard rate units distribute evenly across the entire filter bed . . adjustable nozzles produce fine, well-aerated spray which carries down high volumes of oxygen. For high capacity filters both the Yeomans high capacity type distributor, and the Aero-Filter system are avilable.

Use this coupon to request literature on Yeomans products—please specify

LITERATURE DESIRED:

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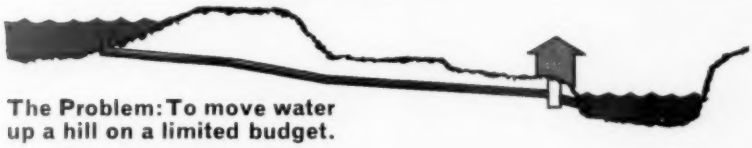
YEOMANS 1999–7 N. Ruby Street · Melrose Park, Illinois

manufacturers of : distributors • clarifiers • mechanical aerators • pneumatic sewage ejectors • digesters • centrifugal pumps T-5917

the problem...



The Problem: To move water up a hill on a limited budget.

The Project: New raw water line for the town of Franklin, Tennessee.

The Engineer: HARRY HENDON & ASSOCIATES, Birmingham, Alabama.

The Solution: Specifying pipe to AWWA Standard C 302-57 as an alternate.

The Result: A saving of $4,689.22 on 2200 feet of 18" CEN-VI-RO Reinforced Concrete Water Pipe that will still be delivering water for generations to come.

Cen-Vi-Ro Pipe . . . engineered and made to your specifications . . . serves you better. When your job calls for concrete pipe, call Concrete Pipe Division, Vulcan Materials Company, Atlanta, Georgia.

CONCRETE PIPE DIVISION

VULCAN MATERIALS COMPANY

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Ramuc® Utility Enamel protects ceiling and walls of tunnel connecting pump and control building with digester building. Floor painted with *Ramuc Floor Enamel*. Despite dampness, mildew and condensation, Ramuc's smooth tile-like finish won't discolor, stays attractive for extra maintenance-free years.

Complete Protection with

INERTOL® PAINTS

Specified for new 9-MGD Westerly Sewage Plant, Altoona, Pennsylvania

Altoona, Pennsylvania, was one of the first U.S. cities to install and maintain proper sewage facilities. With the new, efficient Westerly plant, designed by Albright & Friel, Inc., Consulting Engineers, Philadelphia, Pa., Altoona continues to show outstanding progress in the sewage works field.

Inertol coatings specified for the Westerly plant assure long-term, low-cost protection... easy-to-clean, attractive surfaces that withstand severe sewage plant conditions. Buy Inertol paints direct from the manufacturer. Shipment within three days from our plant, or from nearby warehouse stocks. For complete information about Inertol coatings, write today for *free* "Painting Guide"—an important tool for Design Engineers, Specification Writers and Plant Superintendents.

Ask about Rustarmor®, Inertol's new hygroscopically controlled rust-neutralizing paint.

SPECIFICATIONS FOR RAMUC UTILITY ENAMEL

A glossy chlorinated natural rubber-base coating in color for nonsubmerged concrete, steel and indoor wood surfaces.

CONCRETE SURFACES

Colors: Color chart 560.

Number of coats: One coat of *Ramuc Utility Enamel* over two coats of *Ramuc Utility Undercoater*. For a flat finish, apply two coats of *Ramuc Utility Enamel Flat* to bare masonry—omit undercoater.

Coverage: 250 sq. ft. per gal. per coat.

Approximate mil thickness per coat: 1.2.

Drying time: 24 hours.

Primer: *Ramuc Utility Undercoater* (2 coats).

Thinners: *Inertol Thinner 2000-A* for brushing; *2000* for spraying.

Application: Brushing: *Ramuc Utility Enamel*—brush type: as furnished. Spraying: *Ramuc Utility Enamel*—spray type: add sufficient *Thinner 2000* for proper atomization.

(Write for Ramuc specifications for steel surfaces, and for Ramuc Floor Enamel specifications)

Inertol

INERTOL CO., INC.

A complete line of quality coatings for sewage, industrial wastes and water plants.

482 Frelinghuysen Avenue
Newark 12, N. J.

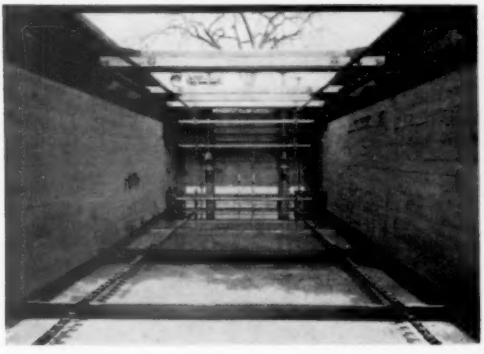
27-H South Park
San Francisco 7, Calif.

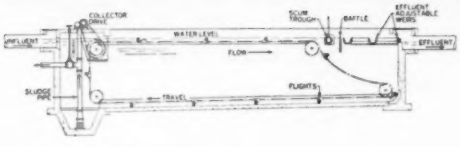
WHICH SLUDGE COLLECTOR

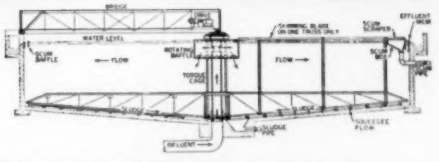
can do the best job for you?

For maximum efficiency . . .
minimum disturbance of flow . . .
choose LINK-BELT
STRAIGHTLINE sludge collectors

For large installations
where construction economies
are vital . . . it's LINK-BELT
CIRCULINE sludge collectors







STRAIGHTLINE COLLECTORS are scraper conveyors made in various styles to handle sludge and scum in *rectangular tanks*. Straightline design means the shortest possible travel for the collected material. It also permits a steady slow speed of the collecting flights that is uniform over the entire floor surface of the tank. This results in maximum efficiency with minimum disturbance to the flow. Straightline collectors can also be installed in the Link-Belt Uniflow settling tank—an improved rectangular design combining a rapidly sloping bottom with a system of multiple effluent weirs.

CIRCULINE COLLECTORS are installed in either rectangular or round tanks. Link-Belt offers four series—R, S, T and C. Series R are usually installed in circular tanks and are used to remove settled sludge from the tank floor and scum from surface of liquid. Series S are for square tanks, or rectangular tanks where sludge is collected only from the influent end of tank. Series T are similar to Series R, except they are built to withstand torques encountered in removing heavy settled solids. Series C have both the economical feature of circular tank construction and the positive sludge and scum collection of a straightline sludge collector.

Sludge collectors are only a part of the broad line of Link-Belt sanitary engineering equipment. Get in touch with the Link-Belt office nearest you. Our sanitary engineers will be glad to work with your engineers, chemists and consultants . . . help you get the finest in modern treatment methods. Or write for Water, Sewage and Industrial Waste Treatment Equipment Book 2617 and Uniflow Settling Tank Folder 2648.

LINK-BELT

SANITARY ENGINEERING EQUIPMENT

15,009

LINK-BELT COMPANY: Executive Offices, Prudential Plaza, Chicago 1. Sanitary Engineering Regional Offices—Colmar, Pa., Chicago 9, Kansas City 8, Mo., San Francisco 24. Sales Offices in All Principal Cities. Export Office, New York 7. Representatives Throughout the World.

PLAN FOR ACTION PROMOTES ADEQUATE WATER SUPPLY

Here's help you can count on

On the opposite page is the third in the current series of advertisements created as a public service by the Cast Iron Pipe Research Association. It's aimed straight at Mr. and Mrs. America through the pages of the widely read *Reader's Digest* magazine.

Similar advertising appears regularly in *U. S. News & World Report*, *Nation's Business*, *Better Homes and Gardens*, *American Home* and *Sunset* magazines.

Every advertisement dramatizes the importance of pure, safe water for home and industry and emphasizes the growing seriousness of the water supply problem. Furthermore, these advertisements *give the reader something to do about it.*

Free Plan-for-Action Booklet

Every reader is offered a free booklet (illustrated on the opposite page) which describes ways for them to get the facts about the water situation in their own communities. A step-by-step outline of action is presented so that, armed with the facts, local citizens can get behind a broad program for extending and improving water service in their own areas.

The third item of assistance offered by the Cast Iron Pipe Research Association to those in the water supply field is a community relations portfolio, also illustrated opposite. It contains ideas and suggestions for public officials to use in their own community relations activities to bring adequate supplies of water to homes and industry in their towns. It tells how informed citizens and officials can work together for improved facilities and adequate rate structures or financing.

This program is already at work—for you. Its impact will be felt more and more as the months go by. For more information and a copy of the booklet, "Water—make sure you'll always have plenty," write to Thos. F. Wolfe, Managing Director, Cast Iron Pipe Research Association, 3440 Prudential Plaza, Chicago 1, Ill.

Three reasons why cast iron pipe is America's greatest water carrier:

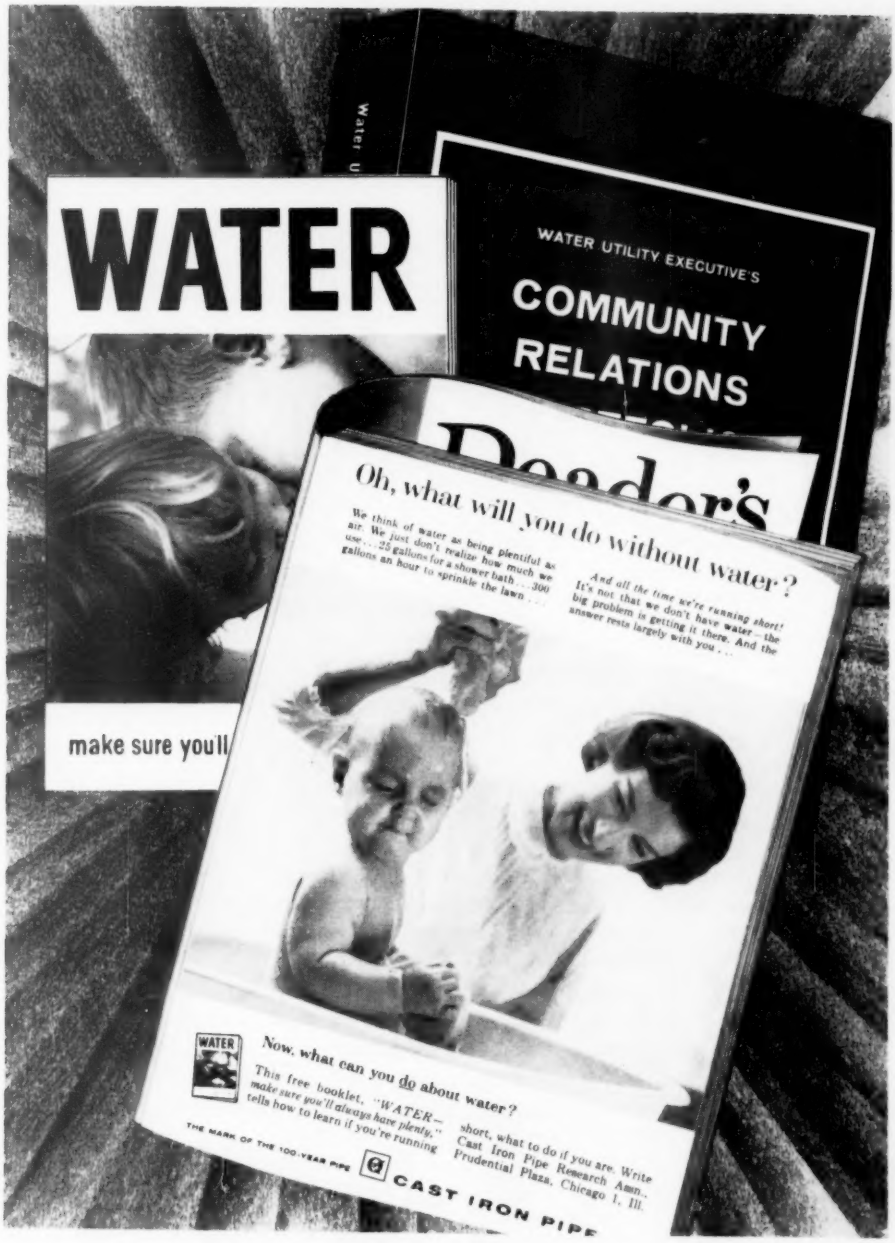
1. More miles of underground cast iron water mains are now in use than of all other kinds of pipe combined.

2. More miles of cast iron water mains are now being purchased and laid than of any other kind of pipe.

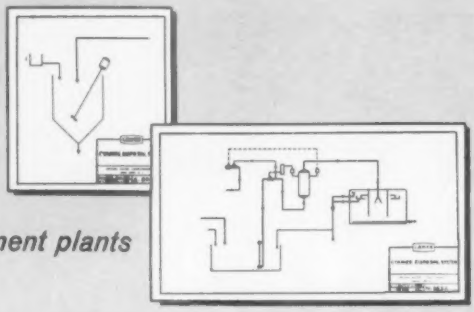
3. Impartial surveys prove that today's water utility officials and consulting engineers prefer cast iron pipe for underground water distribution by an overwhelming majority.

CAST IRON PIPE

THE MARK OF THE 100-YEAR PIPE


WATER
make sure you'll
WATER UTILITY EXECUTIVE'S
COMMUNITY
RELATIONS
Oh, what will you do without water?
We think of water as being plentiful as air. We just don't realize how much we use . . . 25 gallons for a shower bath . . . 300 gallons an hour to sprinkle the lawn . . .
And all the time we're running short! It's not that we don't have water—the big problem is getting it there. And the answer rests largely with you . . .
Now, what can you do about water?
This free booklet, "WATER—make sure you'll always have plenty," tells how to learn if you're running short, what to do if you are. Write Cast Iron Pipe Research Assn., Prudential Plaza, Chicago 1, Ill.
THE MARK OF THE 100-YEAR PIPE
CAST IRON PIPE

from simple units...



...to complex treatment plants

GRAVER SYSTEMS ASSURE

POSITIVE CYANIDE DISPOSAL

From simple batch units to continuous treatment plants, Graver Cyanide Disposal Systems are engineered to provide—

★ POSITIVE DISPOSAL
★ SAFETY
★ SIMPLICITY
★ MINIMUM MAINTENANCE
★ LASTING ECONOMY

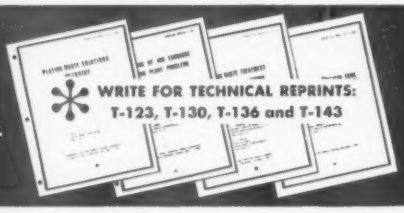
Graver Systems include equipment for oxidation of cyanide to cyanate or complete cyanide destruction by either batch or continuous disposal.

The complete line of Graver equipment for the treatment of cyanide *and all other plating wastes* includes Reactivators®, Rota-Rake® Sedimentation Basins, Ion Exchangers, and specially designed batch treatment units with all controls and accessories.

Whether your problem is cyanide, chromate, acid, alkali or any combination of wastes, Graver know-how, based on years of successful waste treatment experience, will provide the perfect answer in the form of integrated, efficient systems job-engineered to individual plant needs.

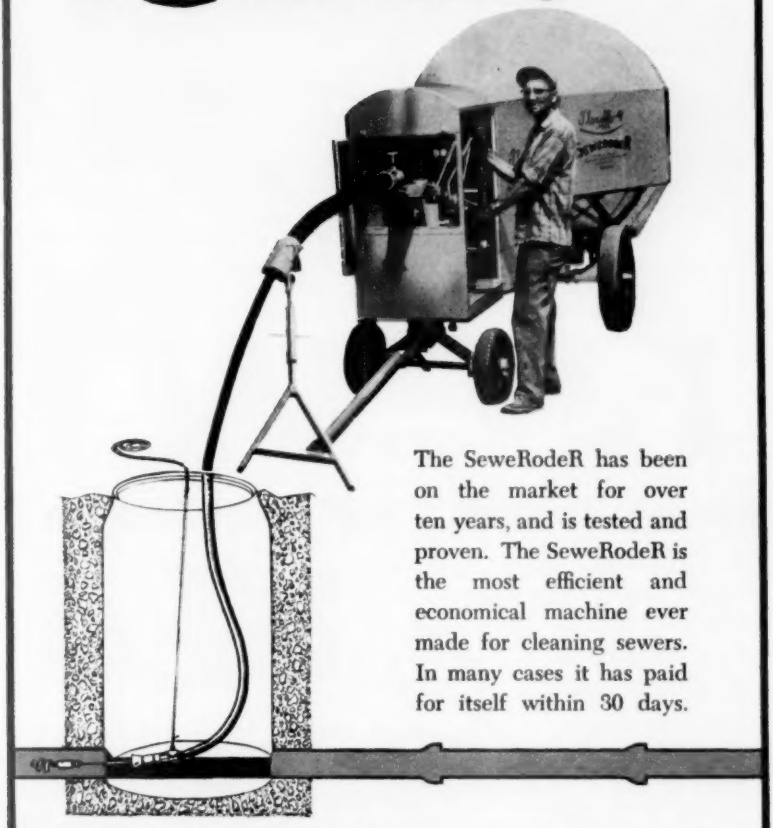
GRAVER®

Industrial Waste Treatment Dept. W-521
GRAVER WATER CONDITIONING CO.
Division of Union Tank Car Company
216 West 14th Street, New York 11, N. Y.



WRITE FOR TECHNICAL REPRINTS:
T-123, T-130, T-136 and T-143

The SeweRodeR is preferred for all sewer cleaning!



The SeweRodeR has been on the market for over ten years, and is tested and proven. The SeweRodeR is the most efficient and economical machine ever made for cleaning sewers. In many cases it has paid for itself within 30 days.

FLEXIBLE INC.

3786 DURANGO AVE., LOS ANGELES 34, CALIF.
1005 SPENCERVILLE ROAD, LIMA, OHIO
415 SOUTH ZANGS BLVD., DALLAS, TEXAS

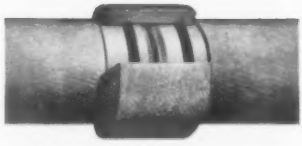
NEW!

5 engineering classifications of "K&M" Asbestos-Cement Sewer Pipe

Now select "K&M" Sewer Pipe that exactly meets the requirements of soil conditions.

These five new crushing strengths in a variety of sizes by "K&M" bring sewer-pipe specifications closer than ever to pinpoint accuracy.

Never before have you been able to match so exactly the requirements of different laying conditions. Now you can select "K&M" Asbestos-Cement Sewer Pipe to suit the depth of cut, the width of trench, the weight of the soil, and the manner of bedding.



"Fluid-Tite" Coupling connects pipes of varying strengths. Assembles in any weather.

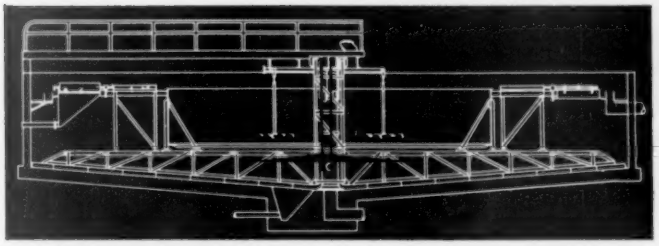
You can use more realistic safety factors . . . attain greater over-all economy . . . minimize over-buying and costly concrete encasement. Select "K&M" Asbestos-Cement Sewer Pipe specifically designed to fit your job.

FREE NEW BOOKLET on "K&M" Asbestos-Cement Sewer Pipe includes crushing-strength table based on Marston formula, plus other information to help you specify gravity sewer pipe. Send for it today.

K·M
BEST IN ASBESTOS

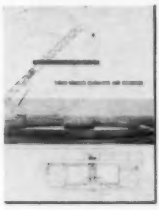
KEASBEY & MATTISON
COMPANY • AMBLER • PENNSYLVANIA

Another Eimco-Process design innovation . . .



Internal sludge recirculators, Non-Clog Diffusers and a sludge thickening deflector are exclusive features of the Type CA Oxidator.

EIMCO-PROCESS OXIDATOR®—WITH CONTROLLED INTERNAL SLUDGE RECIRCULATION—INCREASES SOLIDS AND BOD REMOVALS



The complete line of Eimco-Process Oxidators, Clarifiers and other sedimentation equipment is described in our new Bulletin SM-1005. We will be happy to send you a copy on request.

Developed and introduced by Eimco-Process, and with a number of exclusive features, the Oxidator combines aeration, flocculation and sedimentation in a single circular tank. When aeration and flocculation of the solids are provided prior to clarification, many finely divided and colloidal solids that could not be removed by conventional sedimentation are flocculated and collected with the sludge. The aeration keeps the influent fresh and, combined with controlled internal sludge recirculation, gives increased floccule size, minimizes scum formation, and gives increased suspended solids and BOD removals.

In this unique design, internal sludge recirculation is accomplished through airlifts with intakes below the special sludge pocket protection deflector. By placing the intakes in this protected heavy sludge zone and controlling each lift with a separate valve, optimum recirculation rates can be obtained.

Gentle or intense aeration, adjustable sludge recirculation rates and controlled sludge thickening make the Oxidator the most flexible of all sedimentation equipment. Used alone, it can provide economical intermediate treatment; used with secondary equipment, it can substantially reduce total plant investment.

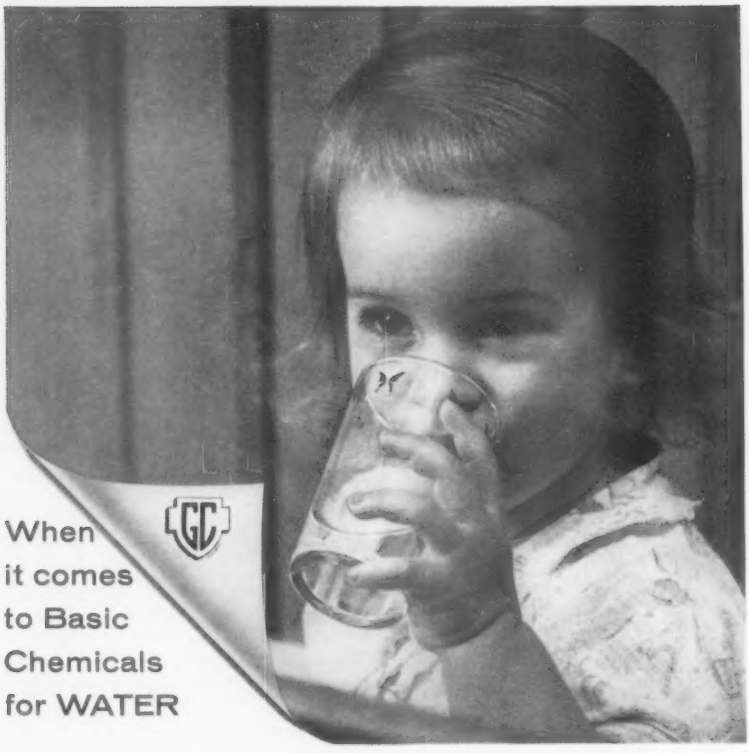
THE EIMCO CORPORATION
Salt Lake City, Utah

B - 394

PROCESS ENGINEERS, INC. *division*
420 Peninsular Avenue
San Mateo, Calif.

. . . another outstanding installation

Two 75 ft. dia. Type CA Oxidators, Puyallup, Washington. Consulting Engineers—Gray and Osborne, Yakima, Wash.



...come to General Chemical!

There are good basic reasons for making General Chemical your source of supply for basic chemicals. Our large-scale production is one. Long experience is another. And there are many more—including consistent high quality and uniformity of product . . . top-notch technical service . . . a coast-to-coast network of plants and distribution points . . . plus efficient follow-through from order to delivery and beyond that to satisfactory performance. That's why—when you need basic chemicals—come to General Chemical for all these products. . . .

COAGULATION
Aluminum Sulfate, Standard
Aluminum Sulfate, Liquid
Ammonium Alum
Potassium (Potash) Alum
Sodium Silicate

FLUORIDATION
Sodium Fluoride
Sodium Silicofluoride
Hydrofluoric Acid

DECHLORINATION
Sodium Sulfite
Sodium Bisulfite, Anhy.
Sodium Thiosulfate

BOILER WATER
Sodium Sulfate, Anhy.
Disodium Phosphate, Anhy.
Trisodium Phosphate
Sodium Silicate
Sulfuric Acid

CORROSION CONTROL
Sodium Silicate
Tetrasodium Pyrophosphate
Sodium Tripolyphosphate

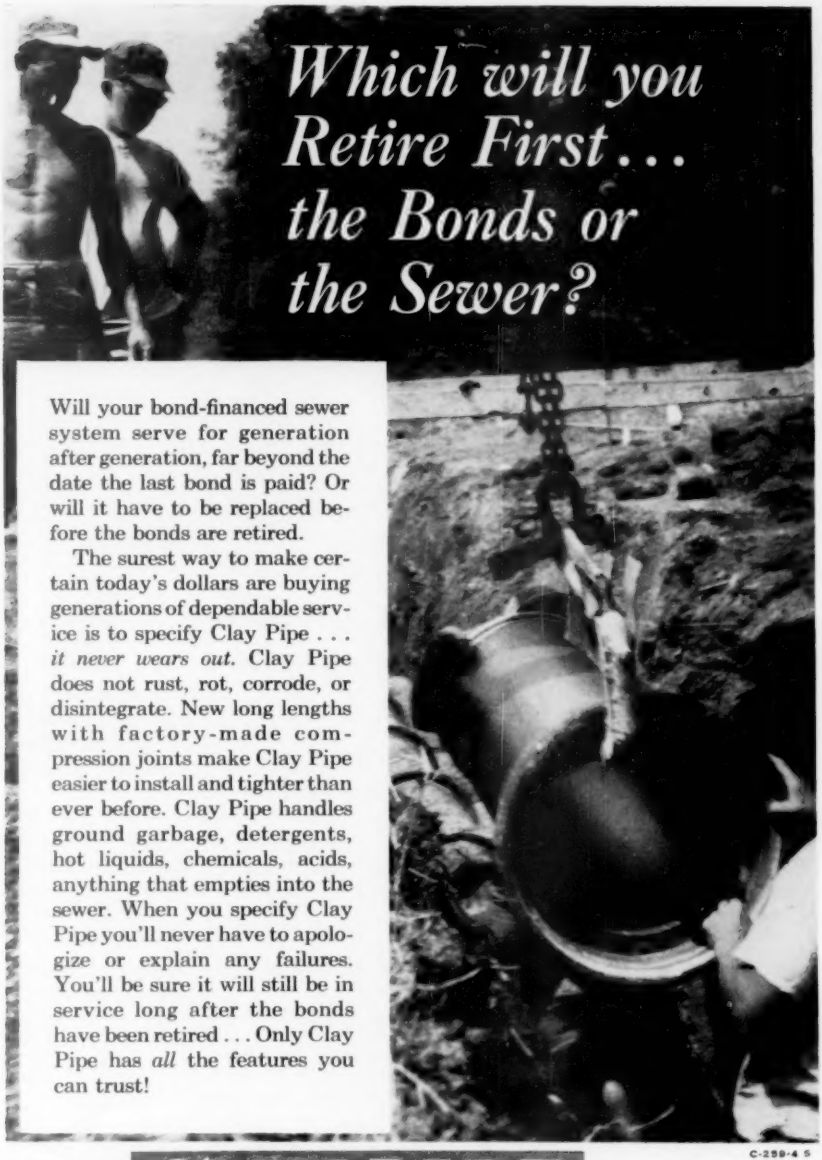
OTHER USES
Aqua Ammonia
Hydrochloric Acid (Muriatic)

Baker & Adamson® Laboratory Reagents and Fine Chemicals

Basic to America's Progress

Allied Chemical

GENERAL CHEMICAL DIVISION
40 Rector Street, New York 6, N. Y.


Which will you Retire First... the Bonds or the Sewer?
Will your bond-financed sewer system serve for generation after generation, far beyond the date the last bond is paid? Or will it have to be replaced before the bonds are retired.
The surest way to make certain today's dollars are buying generations of dependable service is to specify Clay Pipe . . . it never wears out. Clay Pipe does not rust, rot, corrode, or disintegrate. New long lengths with factory-made compression joints make Clay Pipe easier to install and tighter than ever before. Clay Pipe handles ground garbage, detergents, hot liquids, chemicals, acids, anything that empties into the sewer. When you specify Clay Pipe you'll never have to apologize or explain any failures. You'll be sure it will still be in service long after the bonds have been retired . . . Only Clay Pipe has all the features you can trust!
C-259-4 S

Vitrified **CLAY PIPE** Never Wears Out

NATIONAL CLAY PIPE MANUFACTURERS, INC.

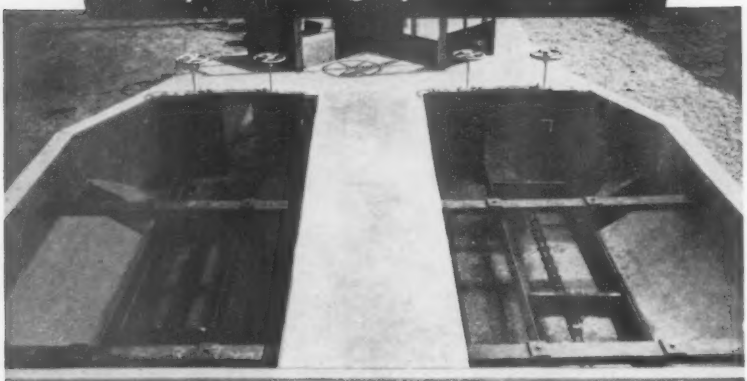
1820 N St. N. W., Washington 6, D. C.

311 High Long Bldg., 5 E. Long St., Columbus 15, Ohio • 703 Ninth & Hill Bldg., Los Angeles 15, Calif.

Box 172, Barrington, Illinois • 1401 Peachtree St., N. E., Atlanta 9, Georgia

REMOVE GRIT

Easily—Thoroughly—at Low Cost



COMPLETE EQUIPMENT

to do the complete job!

PROVIDES CONSTANT OPTIMUM VELOCITY
POSITIVE ADJUSTMENT FOR VARYING FLOWS
HYDRO-DYNAMIC WASHING
AUTOMATIC DRAINING AND REMOVAL

FLOW CONTROLS—exclusive Camp Channel Section and Regulator* maintain constant optimum velocity for effective grit settling, regardless of rate of flow through plant. Velocity can be easily and instantly adjusted to meet changing conditions. Minimum head loss.

*Patented

CONVEYOR—single strand, continuous drag type. Flights carry the settled grit from channel bottom to hopper for washing and removal.

HYDROWASH UNIT—washes grit free of organic matter by producing a turbulent downflow recirculation and agitation of liquor in grit hopper. Organics returned to hopper.

ELEVATOR—totally enclosed, tube type, for slow and continuous removal of washed grit from the hopper. Grit drains as it is being elevated through the tube.

Write for Bulletin No. 249B

Technical Supplement "CR", containing complete design data on the AMERICAN CAMP GRIT CHANNEL *and* REGULATOR, *is available on request with Bulletin 249B.*

AMERICAN WELL WORKS

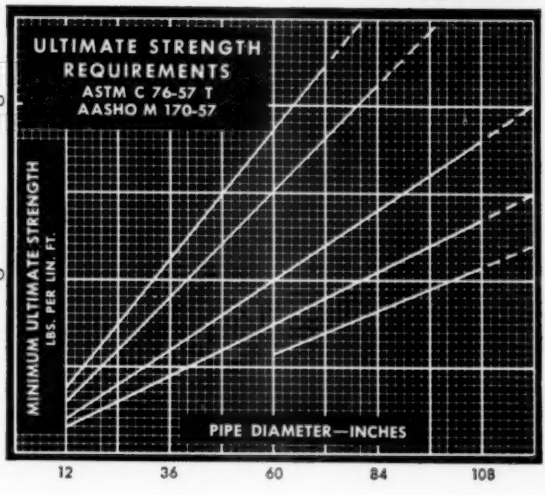
IN OUR 91ST YEAR
110 North Broadway
AURORA, ILLINOIS

Pumping, Sewage Treatment, and Water Purification Equipment
RESEARCH · ENGINEERING · MANUFACTURING

Offices: Chicago · New York · Cleveland · Cincinnati · Kansas City · Sales Representatives throughout the World

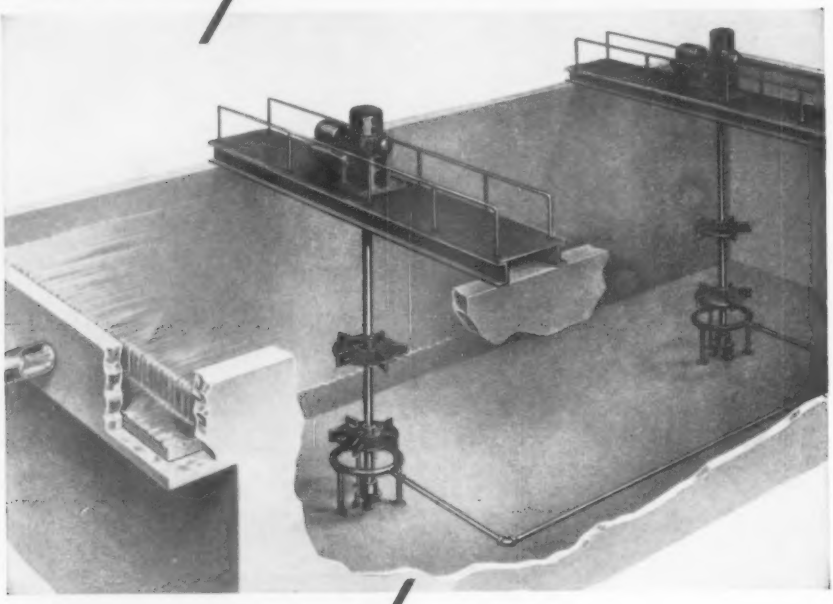
COMPARE THESE CONCRETE PIPE STRENGTHS WITH ANY OTHER

All classes of reinforced concrete pipe for greater strength and safety factor —as well as standard and extra strength non-reinforced concrete pipe—are available from American-Marietta Company to meet ASTM, AASHO and Federal Specifications.



AMERICAN-MARIETTA COMPANY
CONCRETE PRODUCTS DIVISION
GENERAL OFFICES:
AMERICAN-MARIETTA BUILDING
101 EAST ONTARIO STREET, CHICAGO 11, ILLINOIS, PHONE: WHITEHALL 4-5600

IT'S NEW / It's from DORR-OLIVER



THE D-O AERATOR /

- increases oxygen absorption
- reduces sludge clogging
- cuts plant costs

Higher effective oxygen utilization—up to 50% compared with 5 to 6% in conventional systems—enables the new D-O Aerator to meet increased demands of the more concentrated activated sludges in today's biological sewage processes.

It's a brand-new design, proved by extensive pilot and operating plant work. Basic elements are high efficiency turbine type impellers and sparge rings for introducing air under the lower impeller. The sparge ring design virtually eliminates problems associated with conventional diffusion type equipment. Turbine aeration does not depend on constriction to produce small bubble size. There is less possibility of clogging, dead areas and short circuiting of sewage in the event of high entrance velocities.

What's more, overall installed costs are lower than those of conventional units. The new D-O Aerator can be adapted to a variety of tank sizes and installed in existing tanks. For more information write to Dorr-Oliver Incorporated, Stamford, Conn.

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1958 Literature Review

A REVIEW OF THE LITERATURE OF 1958 ON SEWAGE, WASTE TREATMENT, AND WATER POLLUTION

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This section of the Literature Review covers analytical methods and sewage. It will be followed by two other sections dealing with industrial wastes (including radioactivity) and stream pollution. These will be published in the June and July issues of This Journal.

ANALYTICAL METHODS

Biochemical Oxygen Demand

The problem of determining carbonaceous oxidation with the exclusion of nitrogenous oxidation has been the subject of many investigations. Gaffney and Heukelekian (15) studied a number of different methods in order to eliminate observed errors in the carbonaceous oxidation of pure organic compounds and secondary effluents. They found that errors due to nitrogenous oxidation could be eliminated by supplying a C:N:P ratio of 100:5:1. Such a ratio supplies the necessary nitrogen to carry out the carbonaceous oxidation but leaves no excess NH_3-N available for nitrification. Unfortunately, the carbonaceous BOD cannot always be known in advance and the authors had to resort to more practical methods to eliminate the errors due to nitrogenous oxidation. The flash pasteurization of the seed was found to affect adversely the carbonaceous oxidation during a 13-day period which was no doubt due to inhibition of heterotrophic activity as well as that of nitrifying organisms. It was also found that the correction of the total oxidation obtained for the nitrogenous oxidation was not practical for routine BOD determinations even though the method did give a close theoretical value for the carbonaceous oxidation. The authors were able to eliminate the nitrification for periods up to at least 20 days by substituting NO_3-N for the NH_3-N in the dilution water used, thus making possible the determination of the true carbonaceous oxygen demand for a number of pure organic compounds.

The toxic effect of metal ions on the BOD determination has received an enormous amount of consideration by those working in the field of sanitary chemistry and to date the evidence is still conflicting, possibly due to different experimental conditions. Morgan and Lackey (27) studied the effect of copper and chromium on the 5-day BOD of domestic sewage and concluded that chromium is more toxic than copper. However, by addition of EDTA to the substrate, BOD values in the presence of copper (up to 100 mg/l) and chromium (up to 20 mg/l) were obtained, which were comparable to those of the control. It is a well-known fact that EDTA has the capacity to chelate many metal ions and on this basis their toxic action could be inhibited.

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Chemical Oxygen Demand

In the determination of the chemical oxygen demand of industrial wastes containing a high chloride concentration, the use of the silver sulfate catalyst is contraindicated. Bertram *et al.* (3) devised a modification of the standard method which would allow the use of the catalyst in such cases. In their modification, they first oxidized the chloride present by refluxing for one hour and then added the silver sulfate catalyst and continued the reflux for another hour. By so doing, they were able to receive the beneficial effect of the catalyst and prevent the precipitation of silver chloride. (The same procedure was used by the British in their standard method for COD of trade wastes.)

Buydens and Ledent (6) examined three procedures for the COD determination using $KMnO_4$ $(CeSO_4)_2$, and $K_2Cr_2O_7$ as the oxidants. They found that practically the same results could be obtained with permanganate and ceric sulfate. Dichromate gave the highest values but they recommended that the use of the silver sulfate catalyst be omitted since non-uniform oxidation of the AgCl precipitate was obtained. They also recommended against the use of 0.05N $K_2Cr_2O_7$ based on resulting high blanks.

In a study of the COD of citrus wastes, McNary *et al.* (24) found that with such wastes 90 per cent of the COD value was obtained during the first 5 min of refluxing. They, therefore, used a 10-min reflux period (in 50 per cent H_2SO_4) instead of the standard 2-hr period. The optical density of the refluxed solution was read at 650 mμ and the COD determined from a standard curve. Color standards were also prepared in sealed tubes which could be used for a rapid approximation of the COD of citrus waste samples.

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Dissolved Oxygen

Husmann and Stracke (19) used two types of apparatus for the continuous measurement of dissolved oxygen in flowing water. The first type consisted of a pump, electrochemical element, recorder, and flowmeter. The measured current passing between two noble element electrodes was proportional to the dissolved oxygen content of the water. The measured current can be corrected for conductivity effects and is independent of pH above a pH of 6.0. The second type of instrument consisted of an electrode dipping into the flowing water, a resistance thermometer, and recorder. The recorder may be some distance away from the remainder of the apparatus. The water must be flowing

at a certain minimum speed past the electrode, which must be cleaned daily. The second type of instrument is particularly suited for measuring the dissolved oxygen content of aeration basins.

Nusbaum (32) suggested a new modification of the Winkler method for DO. The author substituted sulfamic acid for the sulfuric acid used in the acidification step of the Winkler method. The sulfamic acid can be added either in the dry form or in solution. Approximately 4 g of the dry acid is added, which is sufficient for acidification of the sample and also is effective in the destruction of several mg/l of nitrites. The results obtained were comparable to those using sulfuric acid. The author postulates that on the addition of sulfamic acid to the strongly alkaline solution that the change in pH is more gradual and that all of the nitrite is destroyed before a pH of 3.0 is reached, at which point nitrite will react with I^- to give free iodine.

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Nitrogen Compounds

In the determination of organic nitrogen in various wastes, there may be present nitrogen containing compounds other than amino nitrogen. Such compounds require preliminary treatment before being subjected to the Kjeldahl procedure. Steyermark *et al.* (37) studied compounds containing the N-N, N = N, NO and NO_2 groupings. Their procedure involved the reduction of such groupings by means of a zinc-iron treatment in a formic-hydrochloric acid mixture at water bath temperature. When reduction was complete, the solution was subjected to Kjeldahlization using mercuric oxide as the catalyst. These authors also determined NO_3-N by reacting the NO_3 compound with salicylic acid in H_2SO_4 to form the nitrosalicylic acid. This nitro compound was then reduced with thiosulfate and the nitrogen determined by the usual Kjeldahl method. An almost identical procedure (except on a macro scale) for the determination of nitrogen in N = O and N-N compounds had been published earlier by Dickinson (11). He also used zinc and iron in a formic-hydrochloric acid mixture (with the addition of alcohol) for the reduction, followed by Kjeldahlization. In those cases in which the compound would not dissolve in the HCO_2 H-HCl mixture, either acetic or phosphoric acids could be substituted. The author claims that no catalyst is necessary during the Kjeldahlization. Recoveries of about 99 per cent of the theoretical nitrogen were obtained. Dickinson also used aluminum in a sulfuric acid medium for the reduction of the same type of nitrogen compounds. In this case, the reduction was carried out at about 30°C after preliminary solution on the steam bath. It was found necessary for the aluminum to be added at intervals over an hour period. The theoretical nitrogen recoveries with this procedure, however, were lower than with his other method.

The problem of an accurate and precise method for the determination of nitrates is still being studied by numerous investigators. One of the main lines of study has been the reduction of nitrate to nitrite with sub-

sequent determination of the nitrite formed by the well-known Griess reaction. Middleton (25) found that in the reduction of nitrate to nitrite with zinc and manganese, pH played an important role. This reduction increased with pH to a maximum (100 per cent) at pH 10.2, remained constant to about 11.2, and then decreased. He, therefore, buffered his solution at pH 10.5 with ammonium hydroxide—acetic acid buffer which also contained the manganese. Zinc powder was then added and the mixture shaken for five minutes after which it was filtered and the Griess reaction carried out. This same author (26) investigated the determination of nitrates by the phenolsulfonic acid method. He found that p-phenolsulfonic acid could be substituted for the phenol-disulfonic acid commonly used. The former reagent was, however, less sensitive since the lower limit of its usefulness was about 2.5 mg/l NO_3-N. The author claims that in order to secure reproducible results the nitrate solution must be added to the phenolsulfonic acid and that this order of addition must not be reversed.

One of the other approaches which has been used in the determination of nitrates is the reduction of the nitrate to ammonia and its determination as such. Pappenhagen (33) carried out this reduction by means of ferrous ion in an alkaline medium. The ammonia formed was steam-distilled and determined by means of the pyridine-pyrazalone reaction. Any ammonia initially present was removed by passing the sample through a column of Nalcite HCR cation exchange resin. The sample volume should be chosen so as to contain 0.01 to 0.1 mg of NO_3-N.

Another approach to the determination of nitrates was made by Rippert (34) in which the nitrate concentration was in excess of 10 mg/l. He reacted the nitrate with an excess of a standard ferrous iron solution in a sulfuric acid medium at 110 C. The excess ferrous iron was titrated with a 0.01 *N* $K_2Cr_2O_7$ solution. Details for the preparation of the standard ferrous iron solution are given in the original article.

Greenberg *et al.* (16) compared the brucine method with the standard methods in use and concluded that it was more accurate and precise than either the phenol disulfonic or the reduction method. Its disadvantages are the small sample size that can be used, the toxicity of the reagent, and the concentration range covered (1 to 10 mg/l). Fisher *et al.* (13) also used brucine as the colorimetric reagent for the determination of both nitrite and nitrate, either separately or in admixture. They found that nitrite ions will develop a maximum color with brucine in a 17-per cent H_2SO_4 solution, whereas, nitrate ions required a 50-per cent sulfuric acid solution. By a combination of the two techniques, the total nitrite and nitrate nitrogen could be determined.

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Halogen Compounds

Bellack and Schouboe (1) determined fluorides photometrically with an accuracy of 0.02 mg/l using Na 2-(p-sulfophenylazo)-1,8-dihydroxynaphthalene-3,6-disulfonate (I) in conjunction with zirconyl chloride. The sample must contain no more than 0.07 mg of fluoride. Arsenite was used to

destroy chlorine. If other ions are present to produce an error of 0.1 mg/l the sample should be distilled prior to the test. Equal amounts of I and zirconyl chloride were added and the optical density determined at 570 mμ. The method was found to be applicable to fluoride concentrations of 0.00 to 1.50 mg/l. Nielsen (31) in his determination of fluorides in trace quantities made use of a preliminary concentration of the fluoride ion on Dowex-1 in the acetate form. The fluoride was then eluted with increasing concentrations of sodium acetate and the color development carried out in a hydrochloric acid solution using Erichrome Cyanine R and zirconyl nitrate. Preliminary distillation was found to be unnecessary and fluoride concentration of 1 to 10 γ could be determined with an accuracy within 5 per cent. Koros (20) determined fluorides volumetrically in a solution containing 0.05 to 2 mg F^-. The author carried out the titration with a standard thorium nitrate solution at pH 5.6 using Pyrocatechol Violet as the indicator. The color change of this indicator at the end-point is from a green-yellow to blue. The error claimed for the determination is ± 0.5 per cent.

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Phosphorus Compounds

Benedan (2) determined phosphates turbidimetrically by forming the strychnine-molybdophosphoric complex and found it to be ten times as sensitive as the usual molydophosphate test. The turbidity produced was proportional to the concentration and followed Beer's law between 1 and 12 μg of P in a volume of about 11 ml. SiO_2 does not interfere but PO_3^- must be converted to PO_4^{-3} by refluxing with HNO_3. Carboxymethylcellulose is used as a stabilizer and the absorbance measured at 420 mμ. Murphy and Riley (29) used a single reagent consisting of ammonium molybdate, ascorbic acid, and H_2SO_4 for determining phosphates in sea water. The color was allowed to develop for 24 hr at room temperature or for 30 min at 60°C. The developed color was stable for at least 60 hr. They measured the optical density at 827 mμ and claim that Beer's law is followed up to 500 γ phosphate as P/l. The salt error is 4 per cent with water containing about 19-per cent salinity. Interference from other ions normally found in sea water was negligible. In the study of traces of phosphates in rivers and public water supplies, the Committee of the American Soap and Glycerine Producers (8) found that the methods currently used for the determination of orthophosphate and condensed phosphate gave erroneous results. The causes were claimed to be due to partial hydrolysis of condensed phosphates during orthophosphate determination and to interference from materials commonly occurring in surface waters. P_2O_5 is not picked up by acid hydrolysis if the bonding in the organic molecule is either P-O-C or P-C. This Committee recommended two methods for P concentrations between 0.05 and 0.6 mg/l and 0.6 to 3.2 mg/l.

Cyanogen Compounds

In the determination of cyanides the reagent 3-methyl-1-phenylpyrazol-5-one has been widely used. Malatesta and Dubine (23) substituted diethylacetonedicarboxylate and found that

the color could be developed in the cold in about 8 min and was stable for about 16 min, the optical density being measured at 525 mμ. Beer's law is followed for cyanide concentrations of 0.8 to 2.2 mg. They also found that ethylacetoacetate or ethylbenzoylacetate could be used over a cyanide range of 2 to 5 mg. The color, however, must be developed by slight heating. The first reagent is the more stable and can be used over the pH range of 4 to 7.6. Zdenek (41) determined cyanides in concentrations less than 3 mg/l by reacting them with picric acid in an alkaline solution giving a red-complex, the absorbance of which was measured at 520 mμ. Sulfides in concentrations greater than 1 mg/l must be removed by precipitation with lead acetate. For low concentrations of cyanide a preliminary distillation was made. Schilt (35) used 1-10-phenanthrolene-iron (II) to form a dicyano complex in his method for cyanides. The developed color was extracted with chloroform and the absorbance measured at 597 mμ. Copper and cobalt ions inhibit the reaction. Sulfides also cause interference as well as ferrous iron. The method gave an accuracy of 2 per cent for a cyanide concentration of 4 mg/l and has a sensitivity limit of 2 γ.

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Organic Compounds

The determination of phenolic type compounds in which the position para to the hydroxy group is filled by an alkyl radical has previously been quite difficult by the methods in common use. Tallon and Hepner (39) devised a method to overcome this difficulty. They first reacted the phenolic mixture with Gibb's reagent using a sodium bicarbonate buffer and allowed it to stand overnight. This, of course, formed the well-known blue indophenols with those phenolic compounds in which the para position was unsubstituted. The p-cresol was separated by steam distillation and reacted with diazotized p-hydrazinobensulfonic acid. The reaction is complete in five minutes and the color formed was found to be stable for several hours. The absorbance was measured at 495 mμ. The method was primarily developed for p-cresol concentrations in excess of 1.0 mg/l but by appropriate modification may be extended downward to determine 10 ppb. Good recovery of added p-cresol to waste samples was obtained by this procedure. Yavorskii (40) determined both substituted and unsubstituted phenols by reacting them with an alcoholic solution of xyanthydrol in a hydrochloric acid medium. The author claims that this reagent will react with phenols substituted with alkyl, methoxy, or ester groups. Phenol compounds containing nitro, carboxyl, or halogen will not react. The author gives the color reaction and sensitivity of 17 phenols in the original publication. Hermanowicz and Czarnodolowa (17) investigated methods for stabilizing aqueous solutions of phenols as well as four different methods for their determination. The four methods used were (a) W molybdate, (b) diazotized p-nitroaniline, (c) diazotized sulfanilic acid, and (d) 4-aminoantipyrine. For mixtures of phenols, the authors concluded that the first method was the most useful. They claim that the other three methods also react with nonphenolic type compounds.

Ellman (12) devised a method for the determination of mercaptans at pH 8.0 by reacting the mercaptan anions with bis (p-nitrophenyl) disulfide. The liberated nitrobenzenethiol

anion is yellow and has a molar extinction coefficient of 13,600/cm at 412 mμ and is 99-per cent ionized at pH 8.0. The sensitivity of the reaction is about 1 μg of the mercaptan (as cysteine) in 4 ml. The method appears specific for compounds containing sulfur atoms capable of existing as an anion at pH 8.0. Heavy metals were found to interfere.

The occurrence and determination of organic acids in polluted water and sewage have been studied by many workers. Mueller *et al.* (28) used a chromatographic separation technique for the separation of such acids. The sample was made alkaline, filtered, and then concentrated to a small volume. The concentrate was then made acid with HCl and continuously extracted with ether overnight. The extract was neutralized, the ether removed, the aqueous phase evaporated to near dryness, made acid with H_2SO_4, and chromatographed on a silicic acid column. The adsorbed acids were then eluted with varying amounts of BuOH and the eluate titrated with 0.02 N NaOH. The method is best suited for organic acid separations of 0.002 to 0.075 me for each acid, although, as little as 0.001 me may be determined. The method was extended to the separation of the commonly occurring detergents.

A comparison of various methods for the determination of oil in refinery effluent wastes was made by a subcommittee of the American Petroleum Institute (38). The procedures studied were the infrared technique, direct extraction-pycnometer method, and API 731–53. It was found that the infrared procedure gave the best results; the cost of equipment, however, is quite high. The extraction-pycnometer method had certain advantages (particularly when volatile compounds are present) over the API method 731–53. Extensive tabular data are given in the original publication.

One of the classes of organic compounds which has received increased attention from workers in the field of sanitary chemistry is that of pesticides. The increased use of such compounds has resulted in their appearance in surface waters and consequent exhibition of their toxic properties. One of the problems which has been posed by these occurrences in such waters was analytical determination of trace amounts. A number of papers have appeared in the past year dealing with this analytical phase and will be discussed briefly.

Lane (21) and Newell *et al.* (30) approached the determination of "Phygon" in water from two different angles. The former author based his method on the reaction between Phygon and dimethylamine to form an orange color which is sensitive to 1 γ/ml and is specific for this compound. His results indicated that recoveries of 91 per cent could be obtained. The latter authors recovered Phygon by distillation from an acid solution, extraction with chloroform, and its absorption was determined in the ultraviolet region. This method was applicable to a concentration range of 8 to 250 ppb with an average recovery of 86 per cent. Fullmer and Cassil (14) determined "Tedian" by nitration and treatment with pyridine in an alkaline solution. The optical density was measured at 520 mμ and the concentration range covered was 5 to 50 γ of Tedian. Smith *et al.* (36) determined "Dalapon" by ether extraction, followed by chromatographic isolation. The isolated compound was hydrolyzed to pyruvic acid and then converted to its dinitrocompound and determined spectrophotometrically. The sensitivity of the method is about 0.1 mg/l and recoveries of 78 per cent could be obtained. Brokke *et al.* (5) in their determination of "Aramite" decomposed it to ethylene oxide which, in turn, was converted to formaldehyde and the latter determined colorimetrically. Lane *et al.* (22) deter-

mined N-m-tolyl phthalamic acid at the 0.1 mg/l level by a caustic hydrolysis in which m-toluidine was formed. The m-toluidine was diazotized and coupled with N-naphthylethylene-diamine, the optical density being measured at 560 mμ.

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Metallic Ions

The literature is replete with references to the toxic effect of metal ions to stream life and biological processes. One of the important factors in this field of study is the possession of adequate analytical procedures for the determination of the metal ion present. A difficulty in the determination of chromium has been its separation from iron and vanadium, both of which interfere in its determination with diphenylcarbazide. Dean and Beverly (10) extracted the chromium from a HCl solution with 4-methyl-2-pentanone. Sufficient acid is carried over in the extraction so that the color could be developed *in situ* with diphenylcarbazide. They found the optimum concentration range for the extraction to be 1 to 10 γ Cr (VI). By this means, they were able to determine chromium in the presence of large amounts of iron and moderate amounts of vanadium. Blundy (4) used this same solvent extraction method for separating chromium from nickel and copper.

Selenium has always been one of the more difficult elements to determine in trace amounts. Danzuka and Keihei (9) determined this element in the presence of high sulfate concentration in a formic acid solution with diaminobenzidine at pH 2 to 3. Due to the fact that diaminobenzidine forms an insoluble salt with sulfate it was necessary to add a large excess of ammonium chloride to prevent its precipitation. After allowing the reaction to take place for three hours, the pH was raised to 6 to 7 and the colored complex extracted with toluene and the optical density measured at 420 mμ. Beer's law is followed up to 25 γ of selenium.

Methods used for the determination of zinc are in general quite complicated and in some cases unsatisfactory. Houghton (18) proposed the use of a triphenylmethane dye in conjunction with thiocyanate in an acid solution. In the presence of iron, fluoride ion is used to suppress its effect. The author claims an accuracy of ± 8 per cent and a sensitivity of 0.02 mg/l of zinc.

Cherkesov (7) determined aluminum by means of the fluorescence it produces with 3-hydroxy-2-naphthoic acid (I) at pH 3.0. (I) itself produces a fluorescence between pH 1.9 and 2.3 above which it is colorless. It

was possible to make the test in either solution or on paper. By using the latter method, interference from Th(IV), U(IV), and Fe(III) could be avoided. The method can be used in the range of 0.1 to 0.01 γ of Al. At pH values below 3.0 the sensitivity is reduced and at high pH values Mg interferes.

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Miscellaneous Papers

A number of papers appeared in various scientific publications during the past year which will no doubt be of interest to those working in the field of sanitary chemistry. These papers are included in the following reference list.

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SEWAGE

Physical and Chemical Methods

The effect of effluent weir loading on the performance of primary settling tanks was reported by Brown and DiLallo (16). Tests were made on primary tanks, 156 ft long, 41 ft wide, and 7 ft deep, with surface overflow rate of 585 gpd/sq ft. Increasing the effluent weir loading from 15,000 to 30,000 gpd/ft of length resulted in only minor differences in the suspended solids content of the effluent. These differences were shown to be statistically insignificant.

Small-scale experiments to study the variables which affect chemical flocculation when used together with dissolved-air flotation were reported on by Katz and Wullschleger (72). Flocs were formed in water with either alum and bentonite or lime and bentonite in a glass cell 40 cm deep and 4 cm by 9 cm in plan. They were coagulated for various periods, up to 16 min, by a reciprocating mixer and then subjected to flotation by the addition of air-saturated water to the bottom of the cell. The sizes of the floc particles and their positions at various times after flotation was initiated were determined photographically. It was concluded from the experimental results that the average size of floc particle produced increases with the flocculation period within the range of times studied; and that the rate of rise of a particle with air bubble attached increases with an increase in the particle size. The total amount of floc removal by flotation was increased by increasing the initial flocculation period, but only minor additional removal resulted from flocculation periods in excess of about four minutes.

Model tests to determine the efficiency of a new type of circular sedimentation tank were reported on by Bergman (13). The tank was similar to a conventional Dortmund tank except that the influent was introduced tangentially in two opposing directions into an annular compartment adjacent to the periphery of the tank. The flow was in a spiral motion downward into the tank and then upward through a central cylindrical section

to the effluent weirs. The model tank was a 51-in. diameter cylinder with 14½-in. vertical walls on top of a 60-degree conical bottom. The central cylinder was 30 in. in diameter by 21 in. in depth. The performance of the model tank was studied by measuring the removal of settleable solids from screened sewage and by tracer studies of flow patterns and dispersion at various rates of flow. The performance was compared to that in a similar model of a conventional Dortmund type design, in which the influent was introduced into a small central cylinder and the flow was radically outward to the effluent weir. The new type tank produced a superior quality of effluent, was subject to less dispersion (short-circuiting) and was thermally more stable than the conventional tank. It was also found that temperature gradient has a considerable effect on the tank efficiency. Solids removal was greatest when operating under a positive temperature gradient, i.e., when the temperature in the tank was greater than that of the incoming flow.

The measurement of dispersion in full scale tanks of various kinds was reported on by Burgess *et al.* (17). The movement of activated sludge in a settling tank was traced by means of a water-insoluble dye, in the form of a very finely ground red powder, which was adsorbed by the sludge particles. Samples of the effluent were extracted in a separating funnel and the red solution of the dye separated from the sludge. The movement of activated sludge was also traced by labelling the sludge with sodium chromate containing radioactive Cr^{51}. The results obtained by both methods were in good agreement. Radioactive Br^{82} was used to trace the liquid flow through primary sedimentation tanks.

The "Uniflow Tank," a recent innovation in settling tank design was described by Dallas (24)(25). The basic differences between the "Uniflow Tank" and a conventional rectangular tank are that in the former the effluent troughs are located along most of the length of the tank and the bottom is sloped upward toward the tank outlet end. Advantages claimed for this arrangement are as follows: the tank volume is reduced without altering the overflow rate; despite the reduction in volume, the displacement velocity is increased by only an insignificant amount; the same volume is provided for dissipation of inlet turbulence as in the rectangular tank; the bottom slope aids in sludge collecting; the flow pattern is more stable due to the converging stream lines; and there is less tendency for short-circuiting due to density currents. The results of experimental studies in which a model tank designed according to the "Uniflow" principle was operated with sewage along with a model of a conventional rectangular tank were also included in these reports. The sloped-bottom tank produced very nearly the same efficiency as the rectangular tank. Diagrams to facilitate design of the "Uniflow Tank" are also presented.

The resistance of sewage sludge to flow in pipes was discussed by Chou (19). Due to heterogeneity and variability of material itself and the complicated flow phenomena, the head losses resulting from sludge flow in pipes cannot be computed by direct application of existing hydraulic formulas. Flow is classified into the two main types of (a) flow in suspension and (b) plastic flow. For any particular sludge there is a limiting moisture content, above which the flow will be in class (a) and below which it will be in class (b). With further subdivision of each type of flow into laminar and turbulent stages, there are four categories of flow conditions. Criteria are discussed and formulas are developed for practical application to each type of flow. Taking the moisture content and the origin of sludges

as parameters, a graphical method of statistical nature is suggested to determine the physical properties of sewage sludge which must be known in order to use the formulas.

Biological Filtration

An investigation was made by McNicholas and Tench (88) to determine the practicability of using the trickling filter process as a means of nitrifying the effluent of the Manchester (England) activated sludge plant in order to meet the Mersey River Board effluent requirements of 10 mg/l of nitrate nitrogen. An experimental filter, 5.17 ft in diameter and 6.25 ft deep, was constructed and filled with 4.92 cu yd of media. The bottom 6-in. layer consisted of 4- to 6-in. clinkers with the remaining 5.75 ft of 1-in. material. Nitrifying conditions were allowed to develop and the filter was then loaded at a rate of 250 to 360 gpd/cu yd for a period of four months. The resulting nitrate nitrogen content ranged from 1.3 to 4.6 mg/l.

Despite this poor showing, the loading rates were increased to more economical dosing rates in an effort to determine what nitrification could be expected from such an operation. Loading rates averaging 870 gpd/cu yd were maintained for approximately a year during which time the nitrate nitrogen content ranged from a "trace" to 6.6 mg/l with an average of 3.8 mg/l. Considering the costs of construction and operation, the authors concluded that it would be more economical to buy sodium nitrate and add it to the effluent than to provide nitrification by means of a trickling filter.

After the study of the nitrifying filter was terminated, an investigation of the feasibility of treating the Manchester sewage by the biofiltration process was initiated. Favorable results with the experimental filter led to the construction of a 30-ft recirculating filter. This filter was placed in operation in October but nitrification did not begin until May even though the winter was relatively mild. By October it was apparent that the filter was unable to produce a satisfactory effluent (BOD less than 20 mg/l and nitrate nitrogen at least 10 mg/l) even when the hydraulic loading rate was 80 gpd/cu yd. At this loading rate, 562,000 cu yd of filtering capacity would have been required to treat the anticipated flow and the conclusion was reached that biological filtration was not feasible.

A continuation of the comparison of four grades of trickling filter media in relation to purification, film accumulation, and biological fauna was reported by Hawkes and Jenkins (54). The media, 1½-in. crushed gravel, 2½-in. round gravel, 1½-in. round gravel, and 1¼-in. crushed granite, were placed in four sections of a trickling filter and operated on the alternating double filtration principle for a 20-month period. During this study, it was observed that the relative efficiencies of the four grades of media varied seasonally, with the smallest stone producing the best effluent during summer conditions and the larger media producing best results under severe winter conditions. This was attributed to the fact that the smaller media ponded severely during cold weather with a marked decrease in efficiency. Seasonal film accumulation was found to be greater on the smaller medium which also supported the largest grazing fauna population.

It was concluded that the 1½-in. crushed gravel was best suited to the conditions at Minworth (England) when loaded at an approximate overall rate of 135 gpd/cu yd by alternating double filtration.

The results of experiments conducted at the Ewell (England) Sewage Works to determine the effects of low frequency dosing on filter performance were discussed by Stan-

bridge (120). Three biological filters were used with the distributors fixed so that one revolution was made every 1¼ min, 3 min, and 28½ min.

Shortly after the study began, all the biological film disappeared from the surface of the filter operated at the slowest revolution and several months were required for the filter slimes to adjust to the changed conditions.

It was noted that by controlling the film accumulation, the low frequency dosing produced a high quality effluent year round while the performance of the filters dosed more frequently was considerably reduced during the winter months as a result of ponding. During the summer months, the slower filter was not as efficient as were the more frequently dosed filters but the reduction was insignificant.

Investigations were carried out by Hutchings (62) at the Horsted Keynes and Handcross (England) Sewage Treatment Plants in order to determine the effectiveness of sand filters in improving plant effluent quality. At Horsted Keynes, a 30-sq yd filter was filled to a depth of 1.25 ft with horticultural grit. The filters were constructed so that they could be flooded to a depth of approximately two feet. Facilities were provided for backwashing using filtered effluent and the operation was performed on much the same principle as the rapid sand filter used in water treatment. In order to provide an influent containing a large quantity of humus material, the secondary settling tanks were bypassed and trickling filter effluent applied directly to the bed. Tests were made to determine the efficiency of the unit in removing suspended solids, the length of time the filter would operate without cleaning, how the load and amount of humus material retained on the sand affected the rate of filtration, and what other improvements in the effluent would be affected. The results indicated that the filter had an over-all efficiency of 96 per cent in suspended solid removal and that 33 per cent of the applied BOD was removed. Due to difficulties experienced with the backwashing operation, data as to the rate of filtration and time interval between backwashings were not obtainable.

In order to answer the questions unanswered at Horsted Keynes, a similar experiment was initiated at Handcross. This filter was modified to include an underdrain and backwash system similar to the arrangement in rapid sand filters used for water. The head used for backwashing was also increased from 3.42 ft to approximately 19 ft. Trickling filter effluent without sedimentation was applied to the filter until the head over the sand built up to the overflow level, a height of 1.875 ft. The filter was then taken out of service and backwashed. It was observed that the amount of organic matter retained on the bed varied from 7.5 to 14.5 lb/sq yd prior to washing and 5.6 to 7.1 lb/sq yd after washing. The volume of water used for backwashing was approximately 500 gal/sq yd. Analyses of the effluent and influent revealed that the filter was removing approximately 100 per cent of the suspended solids applied and 67 per cent of the applied BOD. These investigations indicated that the rate of filtration was approximately proportional to the head of water on the filter and inversely with the organic matter in the medium.

Nicholle (95), in reporting on the operational aspects of the rapid gravity sand filters which have been installed at the Pretoria (South Africa) Purification Works, recommends that porous aloxite carborundum blocks be used for the filter bottom rather than the standard steel or concrete floor with nozzles. It was also observed that a sand grading of 0.833 to 0.589 mm will produce an effluent containing 5 mg/l of suspended solids. A coarser sand, 1.397 to 0.701 mm, produces an effluent averaging 8 mg/l

suspended matter in the effluent. The percentage of washwater is reduced to well below the 5 per cent mark when the larger medium is used. Nicholle also recommended that the filters should be operated on a continuous basis since intermittent operation necessitated backwashing within a matter of minutes.

Using a series of glass microscope slides placed in the standard and high-rate trickling filters of the Dayton, Ohio, sewage treatment plant, Cooke and Hirsch (21) conducted a comprehensive study of the slimes associated with the trickling filter process. The study is reported in two sections. The first part deals with the review of literature, the establishment of procedure, and the method of sampling. The second part concerns itself with the makeup and behavior of the filter slimes. The surface films appeared to have a definite structure. Attached to the stone medium was a layer of fungus mycelium, bacterial cells, algae cells or bases of filaments and holdfasts, and protozoa including sessile-stalked species. On top of this fundamental layer was a mass of tissue which included fungal and algal filaments, clusters of bacterial cells, fungi, algae, and free-swimming protozoans and nematodes. Overlying this layer was another layer of fungus cells in which yeasts, bacteria, and protozoans were found but through which the algae seldom penetrated.

From this study the conclusion was reached that sloughing of the filter slimes was not as dependent on the development of a septic layer at the base nor on the browsing or grazing of the metazoal population as it is on the vigorous washing of the excessive growths. It was also noted that the populations of the high-rate filter appear to be relatively uniform whereas the populations of the standard-rate filter are much more erratic due to the intermittent application of sewage.

In a discussion of the Accelo filter system of sewage and waste treatment, Gillard (40) indicated the following to be advantages of this recirculation pattern: (a) smaller primary and final sedimentation tanks are allowed because no recirculated sewage enters these tanks; (b) a favorable bacterial environment is maintained; (c) high dosing rates are permitted; (d) clogging and ponding are eliminated; and (e) continuous loading reduces the fly nuisance problem.

Rankin (104) states that the biofiltration system can be designed to give any degree of treatment between primary sedimentation and complete treatment. In a discussion of this method of sewage treatment, the criteria for the design of such facilities are given along with typical problems.

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Activated Sludge

In a study of the biochemistry of nitrogen in the synthesis of activated sludge, Symons and McKinney (128) found that if the nitrogen supplied

is insufficient to satisfy the high synthesis demand which occurs at the start of each aeration period, excess protoplasm is destroyed and much of the nitrogen incorporated into the sludge during synthesis will be lost later in the aeration period. Neither batch-fed nor conventional systems can operate without a gradual increase in solids or without wasting by withdrawal of excess sludge or loss of solids in the effluent. All inorganic chemical nitrogens are available for nitrogen supplementation.

Three investigations of the effect of temperature on activated sludge have been made. Dougherty and McNary (26) found during a pilot-plant investigation of the treatment of citrus wastes by the activated sludge process that the unit became so overloaded that the heat of its own activity raised the temperature of the mixed liquor from 32.2 to 41°C. They investigated the effect of the increased temperature without the complications of an overloaded system. They found that a unit could be operated at a temperature as high as 36°C with no deleterious effect on the culture or the degree of treatment. As temperatures were increased above 36°C the number and activity of the protozoa began to decrease until, at 43°C the culture was devoid of all protozoa. Sladecek (115) believes that the optimum temperature for obtaining 80- to 90-per cent purification is between 7 and 13°C. Struzeski and Nemerow (125) found that with dispersed growth aeration, BOD reductions increased with an increase in temperature from 10.5 to 30.5°C.

Sladecek (115) found in a Kessener-type plant that best purification is obtained in the presence of 200 to 500 cu mm of organisms per liter and that a significant rise in the quantity of organisms accompanies or precedes bulking.

Porges (103) and his co-workers have studied the oxidation of glucose by aerated sludge. The glucose contained radioactive carbon, C^{14}, at one end of the chain (either C^{14}-1 or C^{14}-6). C-1 and C-6 were incorporated into cellular material at different rates and to varying degrees. A substantial amount of the radioactivity remained in the supernatant liquor and was used slowly, if at all. It was associated with the residual COD. Sugar removal, as measured by reducing power, was practically complete within four hours, although the actual rate of removal was different in each experiment. Radioactivity of the solution was high, even after such glucose removal.

The infestation of activated sludge developed for nitrile assimilation by a wild growth of a predacious fungi (*Zoophagus insidians*), was reported by Cooke and Ludzack (22). The fungi devoured the rotifer *Monostyla* and aeration solids were reduced by as much as 1,000 mg/l in some units within a week. The fungal growth was controlled by treatment with sodium hypochlorite.

Several aspects of aeration have been discussed in the literature. Rohde (108) believes that the solution of oxygen depends mainly on diffused air and only slightly on absorption at the surface. The rate of solution is affected by the bubble size and with fine bubbles, aeration can be accomplished most economically. The theory that an increase in turbulence or intensity of aeration produced by a rotating brush in a shallow tank should permit a reduction in aeration time was tested in Manchester, England (33), and preliminary results showed that neither the BOD nor the suspended solids was satisfactorily removed, nor was the nitrogen stabilized with this operation. Average solids in the aerator were 6,100 mg/l. A reduction of solids to 2,000 to 2,500 mg/l and an increase in the average aeration period did not produce an effluent which met the Royal Commis-

sion Standards of 20 mg/l BOD and 30 mg/l suspended solids.

Morgan (92) reported that two years' experiments have confirmed the fact that diffuser media may be clogged externally by substances such as excessive calcium bicarbonate and ferrous salts and internally by particulate matter in the air supply. All forms of external clogging are aggravated by fine particles in the air supply. Since cleanliness of the air supply is the most important factor, Morgan proposes a new standard of 0.1 mg/1,000 cu ft instead of the commonly accepted standard of 0.5 mg/1,000 cu ft. Using as an aerating device a high-speed rotating disc or cylinder provided with perforations at the periphery for the discharge of air, Zieminski *et al.* (149) found that an increase in the peripheral speed from 586 to 1,150 fpm almost doubled the efficiency of oxygen absorption irrespective of the air-flow rate. An increase in the depth of immersion of the rotating disc also increased the efficiency of absorption, but both increased peripheral speed and increased depth raised the energy requirements. An economic balance would be required to determine optimum conditions.

Several variations from conventional activated sludge have been described. According to Nelson (94) biological oxidation by the Spirovortex system is accomplished in separate aeration and contact units. Contact takes place in one or more circular detention basins designed to create a spiral action of the tank contents. Settled sewage and recycled flow from the aeration unit enters the tank tangentially to cause the spiral motion. The flow is recycled from the contact tank to the aerating device and back to the contact tank enough times to produce the desired degree of treatment. Six plants are now in operation and one is under construction. An experimental two-stage activated sludge plant at Geldern, Germany (83), has operated satisfactorily at 10 l/sec with loading rates up to 5,500 g of BOD/cu m of aeration volume per day. At this loading, 76 per cent of the BOD was removed. At loadings of 2,270 g BOD and aeration for 102 min, a high degree of purification was obtained. Recommended loadings of 33 cu m air/kg BOD were made for complete treatment and 16.5 cu m air for partial treatment. Tapleshay (130) described the Ratedaeration system which is also known as the total oxidation process. The system consists of long period aeration of raw sewage, settling of the sludge, and return of all the settled sludge to the aeration tank. These plants are mainly used for schools, small subdivisions, factories, and shopping centers. For domestic sewage, 24-hr aeration periods based on the 24-hr flow are provided for BOD loadings not to exceed 30 lb/1,000 cu ft of aeration capacity. The settling tank provides a 4-hr detention period based on the 24-hr flow. The rate of return sludge flow is usually a minimum of 100 per cent and often as much as 300 per cent of the design flow. Since the concentration of solids in the aeration tank gradually increases, a portion of the sludge must be wasted to maintain reasonable concentrations. BOD reductions of 75 to 90 per cent are obtained. As a result of experimental work McKinney and his coworkers (87) built a plant to handle wastes from a small cotton bleachery to be operated as a total oxidation system. With 24-hr aeration, it was possible to produce an effluent with less than 5 mg/l BOD from an influent containing 800 mg/l of oxidizable organics. Little sludge was produced and the solids removed at infrequent intervals were completely digested and easily dewatered.

Torpey and Lang (135) have studied the effects of variations in the aeration period on the modified aeration process at the Owls Head plant in New York. Most operating factors

were kept constant. The DO was maintained at about 2 mg/l in the aeration tank, sludge age remained at 0.2 day, and changes in the aerator effluent suspended solids reflected adjustments required to maintain the total rate of solids in the aeration tanks. A variation in the aeration period from 1.1 to 2.7 hr and in the aerator loading rate of 90 to 180 lb BOD caused no marked change in treatment efficiency. As the aeration period decreased below 1 hr, removal of BOD and air demands fell off sharply but the suspended solids removal was not greatly affected until the aeration period was reduced below 20 min. For the year of operation with an aeration period of 33 min and aerator loading of 370 lb, suspended solids removal averaged 68 per cent, BOD removal 53 per cent, and air required 0.24 cu ft/gal. The corresponding values for the previous four years with 2.2-hr aeration were 73 per cent, 60 per cent, and 0.47 cu ft/gal, respectively.

Garrett (37) has shown mathematically and by plant operation that the rate of growth of the sludge is a factor which determines the operating condition within a plant. The principal requirement in controlling the rate of growth of sludge is that a constant fraction of the solids be wasted daily. This is easily done if a constant proportion of the aeration liquor is wasted continually. In laboratory experiments, Dye (31) studied the effect of varying the aeration solids concentration. He found that under his conditions with weak or moderately strong domestic sewage, aeration tank solids in the order of about 1,500 mg/l gave consistently better operating results than did solids in the order of 5,400 mg/l. A loading ratio of 1 lb of primary effluent suspended solids to 25 lb of return sludge suspended solids seemed to give the best results. He also found that during a two-week period, 48.7 per cent of the suspended solids added were removed by oxidation.

At Belleville, Illinois, the activated sludge plant was overloaded during five days of the week and the sludge bulked. As a corrective, Knoebel (77) set aside 25 per cent of the aeration capacity for reaeration of return sludge and digester liquor. The reaeration period was 12 to 24 hr. The sludge density index rose from 0.5 to 1.5, and even to 2.5. While adjustments were being made, the reaeration tank was taken out of service. The sludge index dropped from 1.4 to 0.7 but it returned to higher levels in 36 hr, after the reaeration tank was put back into service.

Vosloo and Finsen (141) found that the aeration of trickling filter effluent in contact with sludge produced by the filters showed that the oxidation of ammonia proceeded at a constant rate until all the ammonia was converted to nitrate. In general, increasing the concentration of sludge increased the rate of oxidation of ammonia. The pH of the mixture depends upon the alkalinity of the filter effluent and the degree of nitrification. In continuous feed experiments the lowest pH obtained was 5.4, indicating that nitrification ceases at about this pH.

An excellent review of advances made in the activated sludge process for the period October 1, 1954 to June 1, 1957 has been prepared by the ASCE Committee on Sewerage and Sewage Treatment (1).

No report an activated sludge would be complete without reference to the essay on the Hyperion Plant by Aldous Huxley (63).

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Disinfection

A summation of the number and distribution of plants chlorinating sewage has been prepared by the Public Health Service and reported by Thoman and Jenkins (134). Of the total plants in this country about 3 out of 10 can chlorinate the sewage while almost half of the population served with sewage treatment contributes to plants which can chlorinate sewage. This is a large increase in the sewage plants with chlorination since the previous census in 1948.

Two articles on chlorination of poliomyelitis virus have appeared this year (74)(143). Both agree that much higher factors of contact time, temperature, and pH are needed for destroying the virus than for killing the enteric bacteria. Thus, the enteric viruses require either a longer contact time at a given temperature and/or pH 7.0, or less pH at a constant temperature and contact time. This confirms earlier data. Indications that the poliomyelitis virus contains six to ten sulfhydryl radicals on the protein molecule (102) makes the interpretation of the required chlorine dose difficult.

Stumm (126) recommends that ozone be considered for sewage sterilization because of its very superior sporicidal and cystical properties when compared with chlorine. His recommendations are based on sporicidal and virucidal studies of special pathogenic laboratory wastes which are now heat sterilized.

Sludge Digestion

Theory and Mechanism

The mechanism of the fermentation of formate to methane by *Methanobacillus omelianskii* by the use of deuterium as a tracer was studied by Pine (101). Formate was primarily converted to CO_2 before reduction to methane. In addition, a limited intact incorporation of deuteroformate into methane occurred.

Attention is called to a study by Smith and Hungate (117) in respect to the methods of isolation and characterization of a Methanobacterium from rumen. One of the conditions for the growth of this organism in culture medium is a low redox potential at about -360 mv.

Kountz and Nesbitt (78) suggest that anaerobic digestion has not received its proper share of fundamental research. If destruction of organic matter rather than gas production became the criterion of digester performance and biological considerations replaced empirical procedures, it should be possible to develop a digestion system requiring less than 24 hr. Progress toward this goal of reduced digestion time was reported by other authors studying both the theory and mechanism of organic destruction and gas production.

Jevreinova *et al.* (68) studied amylolytic and proteolytic processes in the 45 to 60°C as well as the 33 to 37°C range. Amylases were found to be adsorbed on sludge whereas proteases appeared in both sludge and filtrate. Thermophilic ferments were found less readily inhibited than the mesophilic. In controlled temperature digesters operating in steps of 5°C from 30 to 65°C, Golueke (41) found the 50 to 60° digesters to be somewhat superior in terms of per cent destruction of volatile matter, gas produced, ease of sludge dewatering, etc. All except the 65°C tank were superior to the 30°C tank. At 65°C there was very little bio-activity. Volatile acids increased with temperature but nature of acids, composition of gas, and general morphology of the bacterial population were similar in all digesters.

Heukelekian and Mueller (59) showed that greatest reduction of vola-

tile matter in raw sewage sludge is due to the conversion of grease to volatile acids during acid fermentation and subsequently to gas through methane fermentation. The total grease may initially contain 40 to 60 per cent free fatty acids, 20 to 40 per cent esters, and 15 to 20 per cent saponifiables. Little destruction of greases occurs during the acidification stage, but 70 to 90 per cent destruction of total fatty acids occurs during the period of maximum methane production. Observed average values of destruction by anaerobic digestion were 80 to 90 per cent of free acids, 65 to 85 per cent of esters, and 0 to 40 per cent of saponifiables. The results confirm a previous belief that the rate of destruction of grease during digestion is a function of its dispersion and contact with organisms rather than of rate of cellular metabolism of lipids, at least at volatile solids loadings up to 1.0 lb/day/cu ft.

In experiments designed to study the relationship between volatile acid concentration and rate of gas production, Schulze and Raju (114) first computed the theoretical gas production per mole of acetic acid to be 815 ml, 9 ml for propionic acid, and 1,111 ml for butyric acid under proposed conditions of study. In separate experimental units fed with these acids, the maximum concentrations permitting the maintenance of a proper acid content of the digester, together with the percentage of theoretical gas production, were observed. Results showed that 1 liter of digesting sludge converted 0.2 g of propionic, 1.0 g of acetic, and 1.6 g of butyric acid per day, producing approximately 21, 90, and 158 per cent of theoretical gas volumes, respectively. The reason for the wide difference between acids was not evident. From these and other experiments, Schulze (113) concluded that acid producers are less sensitive than methane fermenters to pH, temperature, moisture, and their own waste products.

By slowly increasing the solids concentration, methane gas production at normal rates was achieved (113) at solids concentrations up to 37 per cent with volatile acids in the 1,000 to 2,000 mg/l range, in contrast with normal 3 to 10 per cent solids concentration with acids at a few hundred mg/l. The author, however, considers the possibility of practical sludge digestion at 30 to 40 per cent solids to be a remote one. In plant-scale attempts to increase the digestion rate Morgan (93) found when gas diffusion was used to mix the contents of a digester so that 10-day digestion might be achieved, peak gas production occurred 3 to 4 hr after feeding, returning to prefeed rates in 12 hr or less.

The possibility that *S. typhosa* might survive accelerated digestion was investigated by McKinney *et al.* (86), leading to the conclusion that high-rate digestion with 6 to 20 days retention should not result in a significant increase in health hazard from enteric bacteria. On the other hand, Dożańska and Iwańczuk (29) noted that sludge should be heated to 55°C for 2 hr before digestion to destroy the viability of parasite eggs, although this is affected by desiccation and prolonged anaerobic digestion as well.

Halvorson (51) reported 300 mg/l of a 1,500 mg/l BOD occurring in the supernatant of a digester receiving yeast wastes could be satisfied by simple aeration. The immediate oxygen demand, resulting from Na_2SO_3 and Na_2S can be removed by aeration, rapid action resulting from the use of 3 mg/l $CuSO_4$ as a catalyst. The effect of temperature and various toxic fractions of industrial wastes on sludge digestion was summarized by Viel (140). Toxic effects as signified by a sharp drop in rate of fermentation were reported by Barash (10) to result from 6 mg/l hexavalent Cr, 50

mg/l trivalent Cr, 30 mg/l Cu, 70 mg/l Pb, 200 mg/l toluene, 100 mg/l amyl alcohol, 800 mg/l acetone, or 200 mg/l benzene. Grune *et al.* (43)(44) found evidence that 50 mc/l of radioactive phosphorus (P^{32}) produced a one-third reduction in methane in the digester gas. Iodine^{131}, however, produced no deleterious effects in concentrations of 100 mc/l. However, the uptake rate to initial concentration ratio of the two isotopes differs.

New Developments

Continued interest in high-rate digestion was evident. Morgan (93) discussed the necessary environmental controls and suggested material balance as a method of assuring realistic data. Sawyer (112) concluded that the process is based on sound principles and that high-rate primary digestion will become accepted practice in primary digestion, since the process is rugged and not easily upset, even when fed only once a day, and can conservatively be designed for a 10-day detention period.

Successful applications of sludge digestion to industrial waste disposal problems were reported. In South African villages with sewage flows too low to permit the addition of hardboard wastes, Stander and Gien (121) matured digestion tanks on sewage sludge, then slowly increased the percentage of hardboard wastes, adding di-ammonium hydrogen phosphate as substrate. When ammonia nitrogen was kept at 100 mg/l or less, digestion was satisfactory at fairly low retention periods. Szebellédy (129) reported a 55 per cent reduction in oxygen demand of sulfite and a 63 per cent reduction for sulfate pulp mill wastes when diluted with domestic sewage and digested anaerobically in a pilot-scale plant. An 80 per cent reduction in oxygen demand of citric acid wastes subjected to anaerobic fermentation was observed by Madera (84). Volatile matter destruction was 66.5 per cent and 63.5 per cent of betaine nitrogen was removed by the process. In other experiments, TNT wastes were removed, and 40 types of organic dyes were found to be decolorized by digestion. Roberts (107) found that poultry wastes respond well to digestion with domestic sewage.

O'Neill (97) reported that 1 per cent copper in dry solids caused appreciable reduction in gas yields. Feeding raw sludge heavily contaminated with copper to a digester not previously acclimatized to copper may stop gas production for some time with an eventual recovery. Toxic effects of zinc seem to be higher than those of copper.

New methods of control of sludge digestion were suggested by Grune and Peek (47)(48)(49). Chromatography (91) may be used to separate gases in digester gas analysis, affording a rapid method of keeping watch on the CO_2 content. Electrical conductivity readings on digester liquid can be directly correlated with the total solids content and may be indicative of the condition of the sludge in the digester. While more work is needed to relate ORP theory to waste treatment practice, it appears to be a distinct function of bio-activity of a digesting sludge. Local conditions in a digester can be studied by ORP and flow-through cells have performed for more than 70 days without solution polarization. When used with temperature and pH readings, ORP may become a useful tool (45)(46). For a digesting sludge the ORP shows a steady decline from + 50 mv to − 300 or − 400 mv during the process.

Witherow *et al.* (146) reported research on a new type of anaerobic process in which raw sludge is introduced at the bottom of a tank and forced upward into contact with a digesting sludge blanket. In a pilot plant this anaerobic contact unit was largely responsible for a 60 per cent reduction in COD and an 80 per cent

reduction in suspended solids. A multiple-compartment digester for night soil in Okayama was described by Kimura (76). Liquid passes from top to bottom of each successive compartment and sludge is drawn off for fertilizer after the second compartment. All pathogens are reported destroyed in 20 compartments so that effluent may go to a creek.

At Richmond, Indiana (109), digester capacity was increased to include garbage disposal, increasing the value of gas produced.

Digester Maintenance and Operation

A procedure for starting up a digester without seeding was summarized by Van Kleeck (139). Heating, addition of 10 to 15 lb of lime per day per 1,000 population, and circulation of contents several hours each day are the principal features. Difficulties with a similar procedure at Brighton, N. Y., were outlined by Laird (80). In this case liming followed a prolonged period of the digester in the acid range and severe foaming occurred at a later date. Hatfield *et al.* (53) presented a tabular schedule for starting a digester with seed sludge equal to 0.5 per cent of the weight of liquid in the tank, specifying a routine for increasing raw sludge additions and recirculating the tank contents. In a second table, loadings, per cent reduction of volatile solids, gas production, etc., were summarized for a number of places over the past seven years. A comparison of seeded and unseeded digesters was made in starting up digesters at Sacramento, California (66). Volatile acids reached 1,500 mg/l in the unseeded tank within 10 days and thereafter rose to 3,200 mg/l, from which they receded to 500 mg/l in 3 months. Acid concentration reached a maximum of 2,000 mg/l in the seeded digesters and went down to 200 mg/l in 3 weeks.

Hatfield also showed that in the practical case the capacity of a digester is reduced to 60 to 70 per cent of its rated capacity by scum and sediment accumulations. Laird's report noted a 4-ft accumulation of scum in a single year. This was finally controlled by increasing the tank temperature to 100°F and recirculating by pumping two hours each day. Scum trouble at Joplin, Missouri (116), involved a loss of 50 per cent of the working volume of the digester. Interior piping was damaged by 6 to 7 ft of scum when the tank was drained. This scum contained periwinkle shells from the 20 cu ft/day of snails found to be discharged with trickling filter humus. Langford (81) reported the combating of 4 to 12 ft of scum and restoring of the net capacity of digesters to near design value by gas recirculation. Pieczonka (99) described the tipping of a floating cover and cracking of a gas line by 6 to 8 ft of scum which required four days of continuous application of air to break up after the tank was drained. Scum three feet thick and heavily laden with cigarette filter tips was found (105) in the Clarkesville, Indiana, plant. At the same time eight feet of sand, grit, and leaves were found in the tank bottom. At Boise, Idaho (6), attempts to remove four feet of fine sand by air resulted in separating water and sand and required hand excavation for removal. At Santa Cruz, California (12), 71 calendar days were required to remove 5 to 6 ft of grit by hydraulic means.

Zickefoose (148) reported an unusual difficulty with a digester. High solids in the supernatant taken out in the primary and returned to the digester had an effect similar to elutriation in removing alkalinity from the digester until a critical condition developed. Wind rotating the floating cover on a secondary digester caused repeated failure of a flexible gas line. To overcome this, Webster (142) in-

stalled special steel guides for bumper rollers on the tank wall. At Belleville, Illinois (77), digester supernatant was used to condition a portion of the return activated sludge to overcome shock loads and to increase plant capacity. At Tacoma, Washington (75), anhydrous ammonia was used to overcome the effect of reduction of NH_3 by sludge dilution.

In controlling sludge digestion, Kelley (73) recommended, on the basis of experience in serving Atlanta's six treatment plants with a central laboratory, that pH, CO_2, and volatile acids tests be run simultaneously. This eliminates the effect of errors which may occur in sampling and analysis for any single test.

Digester Design

Baffa (9) summarized the various state requirements for digester capacity, pumps, heating, gas collecting, etc. Extensive uniformity is evident in the data tabulated, although capacity requirements range all the way from 2 to 3 cu ft/cap for heated digesters receiving sludge from plain sedimentation, to 8 to 12 cu ft/cap for unheated tanks with activated sludge. Taylor (133) described a unique digestion plant design for disposing of sludge from individual home cesspools. Three tanks are used. The first provides settlement and concentration of the tankage. Sludge from this unit is drawn intermittently to a digestion tank with fixed intermediate cover and mezzanine compartment. Liquor rises vertically through an 8-in. pipe to an upper compartment where it is heated by coils. Sludge gas beneath the floor forces liquor from the digestion compartment to the upper story where overflow goes to a second digester. Digested sludge is withdrawn from the bottom of the first stage of digestion.

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Sludge Disposal and Utilization

Sludge Concentration, Conditioning, and Disposal

Genter and Kennedy (38) presented a historical review and the current practices of vacuum filtration, heat drying, and incineration of sewage sludge in the United States. They reported that 360 cities, serving 34 million people, have a combined filter area of 208,150 sq ft. The area occupied by the Chicago, Milwaukee, and Hyperion filters were almost 30 per cent of the total. Items considered were elutriation, polymer flocculating aids, equipment for mixing and feeding conditioned sludge to filters, filter media resistance, sludge disposal, and heat drying of sludges.

Preliminary data on the Zimmerman Process for "wet oxidation" of sewage sludge carried out by the Sterling Drug Company and the Metropolitan Sanitary District of Greater Chicago were recently published (4). Results of a 2-ton pilot plant study employing primary sludge, activated sludge, and a mixture of both were favorable from the standpoint of both economics and operation. Sludge is passed through three heat exchangers at flow rates of 20 to 240 gph at a pressure of 120 psi. The temperature of the third heat exchanger is 460°F and oxidation is completed in a baffled reactor. The oxidation products in the reactor, including steam, nitrogen, carbon dioxide, and water reach a temperature of 515°F and are recirculated through the heat exchangers. This mixture eventually is cooled to 150°F and the gases and ash are separated. The ash contains 10 per cent organic matter and can be lagooned without creating obnoxious odors. Estimated costs for a 100-ton per day plant include $2.6 million for capital investment and $120,000 per year for operating costs.

Raw and digested sludges are handled without chemical preconditioning by continuous centrifuging at two primary treatment plants in California (67). A typical result of digested sludge centrifugation shows a solids concentration of the feed of 4.5 to 5 per cent, the cake 30 per cent, and the centrate 2 to 2.5 per cent. Five cubic yards of cake per week is delivered to the city for use in city parks. At the second plant, a mixture of raw sludge and industrial wastes is similarly treated and has an average concentration of solids in the feed of 3.5 per cent while the cake averages 26 per cent solids. The centrifugate contains 1.9 per cent solids and due primarily to its high volume may be affecting the treatment of the raw sewage. Thirty cubic yards of sludge per day are delivered to the city dump for final disposal. Centrifugation, it was concluded, was successful with no preconditioning, can effectively dewater a variety of sludges, and requires simple and inexpensive equipment.

Spohr and Eckenfelder (119) described the Heymann sludge thickening process developed in Germany in 1954 utilizing a vibrating screen and rotary filter press for mechanical sludge drying. This process is patented in the United States and has been installed and tested in sewage treatment plants in Germany, Switzerland, and in the United States, particularly in Green Bay, Wisconsin, and in West Paterson, New Jersey. The sludge is introduced to the vibrating screen from the holding tank by gravity or by means of a pump. It is transported slowly across the vibrator while moisture is removed to the filtrate lines from the bottom of the screen. The mechanism is vibrated at 1,200 rpm involving a double amplitude of 7.82 mm. Following the vibrator, the sludge is passed through a roller press in which additional moisture is removed. The roller may also be vibrated to facilitate additional moisture removal. The unit uses no

chemical conditioning or additives and operates without heating the sludge. The usual power requirement is 3 to 4 kw and operation is intermittent, the frequency depending on the volume and nature of sludge. Results from municipal plants in Germany in 1954 showed a reduction in moisture content of raw sludge from 93.4 to 74.5 per cent. Air drying this sludge for 24 hr further reduced the moisture content to 13.4 per cent. Extensive studies on dewatering sludge for composting in Switzerland was carried out on both raw and digested sludge. The raw sludge was concentrated to 38.6 per cent by the press and the filtrate contained 0.5 per cent solids. In the digested sludge run, the feed had a solids content of 10 per cent, the solids in the screen filtrate were 8.8 per cent, and the concentration of the sludge from the press was 28.6 per cent. These studies were conducted at a feed rate of 790 gph for the digested sludge and 1,800 gph for the fresh sludge. The Swiss studies on digested sludge showed a reduction in moisture from 88.9 to 80.6 per cent through the vibrating screen and a further reduction of moisture content to 75.8 per cent through the filter press. The solids remaining in the filtrate have presented a problem but various methods are available for further treatment. In many applications it is desirable to return the filtrate to a sludge thickener or primary tank. Results from West Paterson, New Jersey, showed that the sludge was substantially odor-free in spite of a strong odor in the feed sludge. A typical analysis shows a feed of 8.1 per cent and a press of 29 per cent solids with a screen filtrate of 5 per cent solids.

Thickening by means of a pressurized recycle stream which introduces fine air bubbles into the sludge resulting in flotation of the solids was described by Katz (71). In batch laboratory experiments on activated sludge at a recycle rate of 200 per cent, it was possible to achieve a concentration of activated sludge from 1 to 4.5 to 5 per cent in ½ hr and 6 per cent solids after 6 hr, with a separation rate of 1.2 fpm. In pilot-plant studies, using continuous flow of activated sludge, 3 hr were needed to obtain a concentration of 5.5 per cent as compared to 1.5 hr in the laboratory. With a mixture containing equal parts of raw and activated sludge, it was possible to obtain 7.7 per cent solids in ½ hr and with a raw sludge alone, it was possible to obtain 10 per cent solids in ½ hr. The advantages of the process were (a) a shorter detention time, (b) possible higher solids concentration, and (c) greater control of the process.

The Buchenhofen, Germany, sewage disposal works, serving a population equivalent of 40,000 utilizes sonic screens, sonic filters, and pressing as a means of sludge treatment for final disposal (8). The screens remove particles up to 3/64 in. in diameter. The sonic filter, by virtue of a vibratory rotary motion of a stainless steel wire mesh which results in coagulation of the particles, produces a sludge of 78 per cent moisture. Pressing further reduces the moisture to 60 to 65 per cent. The advantages of the process are (a) economic, (b) little area needed (as compared to drying beds), and (c) operation independent of weather conditions.

Papers presented at the Conference on Anaerobic Digestion and Solids Handling at Manhattan College in 1957, have been published in book form (85). Included are four papers dealing with vacuum filtration and sludge conditioning.

Bargman *et al.* (11) reported on extensive experiments carried out at Hyperion in an effort to recover and to filter economically all the sewage solids. Solids handling practices in the past resulted not only in the loss of approximately 40 per cent of the

plant solids but also in a deterioration of the quality of the final effluent or imposed too great a load on the aeration tanks. In an attempt to improve filtration no less than 26 different items were tried with varying degrees of success. Some of these included equipment changes, changes in temperature of digestion, heating and freezing of the sludges, use of precoats, interstage elutriation, and varying the stirring and pumping rates of the sludge. It was concluded that coagulant aids offered the best promise. Thirty-three synthetic polymer coagulants were tested, most with no improvement of filterability. Separan 2610, a polyacrylamide, was selected for further study. It was very effective on elutriated sludges and resulted in increased filtration at 0.03 per cent Separan and also resulted in a decrease of about 27 per cent in the amount of $FeCl_3$ used for conditioning. Tests on two experimental organic polymer coagulants proved very successful. They would increase the filtration rate to 30 psf/hr with great savings in $FeCl_3$. This report also summarized the economics of sludge filtration in respect to the use of sludge as a fertilizer and summarized the status of vacuum filter installation in the west coast states.

Flynn (35) reported on the use of dynel cloth on the sludge vacuum filters at the Bird Island Sewage Treatment Plant in Buffalo, New York. The dynel cloth was much superior to canton flannel or nylon cloth. It was found to be inert to acids, weak alkalies, bacterial decomposition, and mildew. On the basis of experimental runs, there was an increased useful life of over 800 per cent and a concomitant economy due to less frequent washings and shutdown period when using dynel filter cloths as compared to the canton flannel.

Stillingfleet (123) reported on laboratory and full-scale plant experiments of pressing digested sludges in a ram at 80 psi. It was found possible to decrease the moisture content to 46.2 per cent with a 1 per cent dose of aluminum chlorohydrate with a pressing time of 17 hr. Laboratory tests using the specific resistance as an index of filterability showed the feasibility of using aluminum chloride as a conditioning agent equal to that of aluminum chlorohydrate. The effects of elutriation, consolidation time, mixing, and "fines" are discussed briefly.

Taylor (132) described laboratory experiments on conditioning of humus sludge for filter pressing using aluminum chlorohydrate, cationic surface detergents, lime, and calcium salts. Aluminum chlorohydrate at 1 per cent gave optimum filtration for a sludge containing 5 to 6 per cent solids. Cationic detergents at 0.4 per cent were equal to the aluminum chlorohydrate in filtration rates. Synthetic polyvalent electrolytes such as krilium and Separan 2610 were found to be ineffective. Results suggested that the action of calcium was due to the formation of calcium hydroxide micelles which are slightly charged due to ionization. Dosing the sludge with 1 per cent calcium chloride and 0.4 per cent sodium hydroxide gave results similar to a 5 per cent lime alone and 1 per cent aluminum chlorohydrate. Best results were obtained by filtering immediately after the addition of the chemicals. The pH of the sludge did not appear to be significant although there was a change in the optimum concentration with a pH change. In comparison with heat treatment of sludge, aluminum chlorohydrate, cationic detergents, calcium chloride plus caustic soda, and lime were all more costly.

Operating results of a 10-by 10-ft coil filter at Racine, Wisconsin, were reported by Hay (55). Filtration rates averaged 3 psf/hr with a 10 per cent lime and 2.7 per cent $FeCl_3$ dose.

A comparison of costs using $FeCl_3$ alone and lime with $FeCl_3$ showed, for the latter, a savings of $5.09 per ton of solids on a dry weight basis. It has been possible to increase cake production to about 4 to 4.5 psf/hr with a moisture content of 70 to 72 per cent. Difficulties have been experienced in sagging of the coils due either to a buildup of carbonate or silt or the high salt content in the well water used for spraying and washing the coils.

Jeffrey (66) reported that dewatering of primary digested elutriated sludge by vacuum filters using wool filter cloth showed a failure of the cloth after 39 and 70 hr of use. Dacron is now in use and has been in use 1,350 hr with no sign of failure. The cake has a moisture content of 65 per cent and is given away, primarily to local nurseries, ranchers, and the city for its parks and golf courses.

Haseltine (52) has reported on the experience of filtering and incineration of a combined raw primary sewage sludge and tannery waste sludge at Williamsport, Pennsylvania. Monthly averages for the vacuum filter operation indicate that over the entire year only 1.15 psf/hr sludge solids were handled with lime and $FeCl_3$ dosages of 7.3 per cent and 4.25 per cent, respectively. Annual averages indicate only 71.6 per cent of the sludge solids applied to the filter are recovered. Although this recovery could be increased with increasing $FeCl_3$ dosages, the filter rate would not improve and the cost of sludge disposal was thereby increased. It was found that filter rate was more dependent on the solids content of the applied sludge than on the amount of $FeCl_3$ used. An analysis of the amount of oil used in firing the incinerator showed that most of the oil is used to evaporate the cake moisture and on the average, almost as much oil is required to bring the incinerator up to temperature as is required to burn the daily charge of sludge. It was concluded that if the charge to the incinerator were increased, the efficiency of the incinerator would be improved. The average concentration of the sludge solids applied to the vacuum filters was 8 to 10 per cent.

Forrest (36) described the plant experiences of primary sludge pressing. The feed sludge, which averages 6 per cent solids, is treated with 0.3 per cent copperas and 1.0 per cent lime, and pressed at 60 psi. The press consists of 29 cast iron trays containing cloth between the trays. The chambers are 34 in. square by 1.5 in. thick containing a total pressing capacity of 30 cu ft. Polyvinyl chloride media was reported superior to hessian, nylon, or polyethylene, and is usable for two years. Sludge output is 860 tons/yr, containing 65 per cent moisture and costs $5.70 per ton of pressed cake.

Dahlstrom and Cornell (23) discussed filtration problems and the results obtained from equipment improvement on small-scale and full-scale practices. In an effort to reduce or eliminate blinding of the filter medium, the Rotobelt filter was developed, featuring a roller which allows for complete discharge of extremely thin cakes (to 1/16 in.). Also incorporated into the unit are a metallic medium in the form of a woven stainless steel webbing which results in flexing and further removal of any material including chemical buildup. To further remove any buildup the webbing is sprayed after passing through the roller. These improvements have resulted in more rapid filter rates due to a more effective use of vacuum, resulting in a reduction in chemical requirements along with an increase in cake solids.

Trubnick and Mueller (137) reviewed some factors affecting sludge filterability, including filter media, the sludge characteristics such as particle size, compressibility, viscosity,

chemical composition, and sludge concentration. Evidence is presented that raw primary or secondary sludges are more filterable than digested sludges. At the present time in this country, there are 57 plants in operation and 24 more under construction where fresh primary and/or secondary sludge is being dewatered by means of vacuum filters. Those factors which the plant operator can control to some extent, such as coagulant dosage, conditioning technique, contact time between the coagulant and the sludge, and vacuum are discussed.

The Minneapolis-St. Paul Sewage Treatment Plant has effectively substituted a 32- by 32-mesh saran cloth on its vacuum filters for an 8-oz canton filter cloth (2). This has resulted in a decrease in the amount of chemicals required for coagulation, a decrease in the number of times the filter media needed to be washed and acid cleaned, and generally decreased or eliminated most of the blinding difficulties. The average service life of the four saran cloths was 8,747 hr, compared with only 433 hr for the flannel. The vacuum filters receive undigested sludge having an average solid content of 7.6 per cent. The dewatered sludge is then incinerated in a multiple hearth incinerator. The sludge entering the incinerator has a solids content of 27 per cent.

Howells and Dubois (60) have reported a study of sanitary engineering design facilities of 20 small secondary sewage treatment plants which will receive federal financial aid under Public Law 660. These plants were representative of those in the "Ten States" receiving federal aid and are designed for 600 to 12,500 population. Of these 20 plants, 15 will dewater sludge on open drying beds, 2 will utilize lagoons, and 3 will employ mechanical dewatering devices.

South (118) described the installation of an asphalt paved sludge drying bed at Salt Lake City. The asphalt was substituted for the top 6-in. layer of graded sand regularly employed and resulted in a reduced drying time, increase in the per cent solids of the dried sludge, and a saving of $84.50 in maintenance and operation per drawn bed. The sludge disposal facilities at the Detroit Sewage Treatment Plant were described by Burley (18). Raw sludge is conditioned and vacuum filtered. The dried cake plus grit and scum from the sedimentation tank is then ashed in a multiple hearth furnace. The ash is quenched and pumped to lagoons.

Trubnick (136) reported on studies of coliform survival in the cake of dewatered fresh sludges. In general, increasing the pH resulted in a decrease in the number of coliforms. In the range of pH 11 to 12, the coliform count was reduced to an order of magnitude not exceeding 10^3 per g of sludge. Addition of $FeCl_3$ also resulted in a decrease in the coliform count, but beyond an optimum dosage there was an increase in the coliform count. Coliform counts determined on dewatered fresh sludge which had been stored on the ground for a period of up to six months and more, indicated that densities of the organisms did not increase; in fact, there was a reduction in the numbers as the result of exposure to weathering. Efforts are being made to establish whether there is a correlation between chemical dosage required for optimum dewatering rate and the colicidal requirements with any given sludge.

Sludge Utilization

The recovery and utilization of vitamins and proteins of sludges continued to occupy the interest of a number of investigators. Hurwitz (61) summarized studies carried out since 1952 at the University of Illinois on the feasibility of utilization of heat dried activated sludge as a source of vitamin B_{12} and nitrogen for pigs and poultry and nitrogen for ruminants.

Results indicated that activated sludge at a level of 2 per cent of the diet by weight is a safe and adequate substitute for pure crystalline vitamin B_{12} for the pig. At a 6 per cent level the activated sludge proved toxic while at 4 per cent no adverse nor stimulatory effects were evident. For chicks the optimum was found to be 1 to 2 per cent and extra benefits from "unknown growth factors" as compared with the use of the purified vitamin B_{12} were found. Activated sludge was found to destroy the vitamin D in the feed but this could be prevented if the vitamin D was given as an oil soluble stable complex. With ruminants, activated sludge was found to be an adequate source of amino acids and all the essential amino acids, with exception of methionine and cystine, were present in adequate amounts. Activated sludge was found to be equal to soybean oil meal or urea with regards to nitrogen retention and had a biological value of 69 as compared with 60 for the soybean oil meal. There were no pathological symptoms produced in the tissues of either the chick or the pig. The tissues of animals fed rations of activated sludge when examined histologically, were similar to those of the animals fed a standard diet. The criteria for these experiments were usually weight gain, or delectability of the activated sludge as determined by ad-libitum feeding. The amino acid content, the vitamin content, and the trace metal analysis of the activated sludge are given. The activated sludge was obtained from the Metropolitan Sanitary District of Greater Chicago Sewage Treatment Plant.

Dougherty and McNary (27) reported the results of laboratory experiments concerned with the production of protein and vitamins of the B group from activated sludge from the treatment of citrus wastes. They found that the protein content, ranging from 28.9 to 43.8 per cent, was high enough to be considered as a protein supplement in animal feeds; and that the vitamin B_{12} content of the sludge was high enough for it to be considered as supplement in chicken feeds. The experiments carried out indicated the variation in the vitamin content as a function of the nitrogen, phosphorus, and cobalt levels in the mixed liquor. In general, increasing the nitrogen concentration resulted in an increased vitamin B content with the exception of thiamin; and with increased cobalt there was an increase in the vitamin B_{12} content. These results were uniform with a good decrease in the BOD and a good settling sludge.

Elbowicz *et al.* (32) were able to extract 20 to 75 γ of vitamin B_{12} from 2 kg of activated sludge. The addition of $Co(NO_3)_2$ to the waste doubled the vitamin B_{12} content in the sludge.

Kamikubo (70) reported the presence of as much as 30 γ/g of vitamin B_{12} in the supernatant of digested activated sludge. Rumpf (110) noted that 10 tons of sludge produce as much B_{12} as 8 tons of fish liver.

The editors of *Organic Gardening and Farming Magazine* (7) have released the results obtained from questionnaires from 32 cities and 36 states on the practice, acceptability, value, and experience in the use of sewage sludge as a soil conditioner. The information from the cities includes the annual sludge output, the nitrogen and phosphorus content, the sales trend, and the price of the sludge. The information from the states, in tabular form, summarizes the general practice of sludge disposal. Factors such as sludge cost, amounts to use, how to use the sludge, and safety in handling sludge are discussed briefly.

Hall (50) commented that in South Africa the guiding principle for sludge disposal is that the sludge be fully recovered for application to land and be in a condition that is readily acceptable to the farmers. This would mean a dry and innocuous sludge. In

South Africa the drying bed appears to be the most economic solution to sludge disposal primarily because of the high evaporation rate of 80 in./yr. Sludge from the supernatant liquor conditioning tanks may be dried directly on beds although it does dry a little slower than primary digested sludge. An alternative method of disposal of supernatant liquor is to apply it to well prepared terraced land, allow to dry, and dig in. At the end of 12 months, the resulting 9 in. or so of tilth can be readily sold as a fertilizer.

Composting

The feasibility and advantages of composting municipal refuse and garbage in conjunction with sewage sludge have been demonstrated in Europe. Gordon (42) has published a detailed report of two municipal composting plants in the United Kingdom. The Kirkconnel Refuse and Sewage Treatment Plant, serving a population of 45,000, has operated successfully for 4 yr, producing 550 tons of compost per year. The composting method employed is, basically, the Indore process with modifications for proper drainage and more frequent turning. The plant handles daily about 2,150 gal of primary sludge at 96 per cent moisture and 6 tons of refuse having a density of 20.7 lb/cu ft. In the composting process, the wastes are mixed in the proportions of 1,200 gal sludge to 1,800 lb dust and 800 lb of vegetable matter. To facilitate draining, the mixing is accomplished by adding 720 gal of sludge to a 9-in. layer of the refuse and building up these layers until the mixing bin is filled. Total composting time is 5 to 6 wk at a maximum temperature of 180°F, falling off to 125°F during the last week. An analysis of operating costs shows a profit from the sale of compost of $960 per year and a net cost of refuse disposal of $638 per year. The over-all cost of operating the entire plant is $1,531 per year, exclusive of depreciation and capital repayment.

The Bellozanne Valley Refuse and Sewage Treatment Plant, on the Island of Jersey, serving a resident population of 57,000, which increases to over 90,000 during the summer, will compost refuse and thickened, digested activated sludge. The sewage plant has not yet been built. The plant which has been in operation approximately 1 yr, handles 60 tons of refuse per day in a 6-story fermentation cell composting unit. This unit, operating on the principle of intermittent disturbance which provides aeration, has a detention time of 1 day per unit and a further maturing time of 5 to 6 wk. Fermentation reaches a peak in the 4th and 5th story where the temperature is 140 to 160°F. Estimated costs are given. Results of 4-yr pilot-plant studies demonstrated the feasibility of composting thickened activated sludge with the refuse, resulting in a satisfactory and marketable product.

Data supplied by Weststrate (20) on composting in The Netherlands have been summarized. The "V.A.M." Refuse Disposal Company, Limited, a Government company, contracts with certain municipalities to take their refuse at a cost of 8 to 36¢/yr/cap, depending on transportation costs. The company is self-supporting as a result of the total income obtained from the municipal payments, salvage, and sale of the compost. In two of the larger plants, composting is accomplished by windrowing for a minimum of 6 wk. After decomposition, the rough compost is conveyed to a separating device termed a "rasping machine" where fine particles are screened out and the larger organic clumps are broken down to produce a uniform product. Currently, 25 per cent of the refuse in The Netherlands is processed into compost. In addition to common practices, wherein the farmers apply about 13 to 17 tons of

compost per acre every 4 yr, the heat derived from the decomposition of the refuse has been utilized to protect crops from freezing during the winter. This practice has resulted in an extra winter crop.

The papers presented at the meeting of the International Research Group on Refuse Disposal (IRGR) held in Düsseldorf contain instructive information on the practices, concepts, and basic findings in composting of refuse and sewage sludge (64)(65). Composting research in Germany, The Netherlands, Belgium, France, and Switzerland was detailed and emphasis was given to the problems, methods of evaluation, and use of refuse compost in various agrarian enterprises.

A patent was assigned to Pierson (100) for windrow composting of a nonsegrated garbage refuse and sewage sludge mixture. Originally the material is fermented anaerobically until the temperature of the stack rises to 55°C at a moisture content of 60 to 80 per cent. The stack is then turned and decomposed aerobically. Aerobic decomposition is maintained at 40 per cent moisture and decomposition time is from 9 to 21 days.

Wiley (145) reporting on further studies of high-rate composting, found that if the temperature was maintained at 131 to 145°F by water cooling, decomposition was much better than when the temperature in an insulated unit was 153 to 162°F. Cooling below 120°F did not prove to be desirable. Heat studies showed that there were 10,000 to 12,000 Btu/lb of volatile solids lost or decomposed. It was found undesirable to preheat the compost material to 122°F, because under these conditions the decomposition was poor and the pH remained below 5 for the entire run. Steffes (122) reported on successful composting operation at Williamston, Michigan, population 2,500. Garbage plus dewatered raw primary sludge containing 35 per cent solids is composted in a Riker composting system which consists of steel bins and forced air. The temperature is 125°F and composting is complete after 21 days. Operating costs for an 18-month period have been $3.40 to $4.75 per incoming ton of material and sale to date to the farmers and home owners has been at $40 per ton. The operation is odor free.

Bangkok, Thailand, population 1,000,000, is constructing what is reported to be the world's largest mechanized refuse composting plant (3). The plant will produce nearly 90,000 tons of compost a year and is designed to receive 1,500 cu yd of refuse daily. The raw composting material will be separated magnetically, shredded mechanically, and refined in separators which remove fragments of nonferrous metal and ceramics. Sewage sludge will be mixed with garbage to form the raw compost. If sludge is not used, the garbage will be mixed with water. Tests effectively prove that the compost has value as a fertilizer.

A detailed instructive historical review of composting refuse alone and with sewage sludge was given by Wylie (147).

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Detergents

In a laboratory study of biological degradation of synthetic detergents, Ryckman and Sawyer (111) found that anionic detergents, with the exception of alkyl benzene sulfonates derived from propylene, were completely decomposed. The breakdown of alkyl benzene sulfonates occurs when the benzene group is attached to primary or secondary carbonation of the alkyl group. Tertiary alkyl benzene sulfonates were not completely decomposed biologically.

Oldham (96) investigated the effects of non-ionic detergent Lissapol N on purification of sewage by large-scale trickling filters. Concentrations of 13 and 26.5 mg/l (active matter) of the non-ionic agent were added to settled sewage just prior to the trickling filter units. No adverse effects were observed when the trickling filter loadings were normal and 13 mg/l Lissapol N was used. Nitrification was retarded to a greater degree under overloaded conditions in presence of Lissapol N.

Similar observations were made when 26.5 mg/l Lissapol N was used. This non-ionic detergent did not appear to be biologically decomposed and approximately 70 per cent of the detergent added passed through the filters.

Downing and Scragg (28) found that the presence of detergents in sewage caused a marked decrease in the absorption coefficient of oxygen in diffused air activated sludge experiments. The extent of reduction may range from 30 to 50 per cent depending on the type of air diffuser, strength of sewage, and air flow.

Truesdale (138) studied the foaming tendencies of sewage, effluents, and tap water containing varying concentrations of mixed household detergents. The amount of foam produced in a given liquid increased linearly with the concentration of active agent; the tendency to foam was greatest in tap water (although no foam was produced until 2 mg/l active matter was present), and decreased as pollution increased. The weight of active agent lost to the foam phase from solution and the volume of foam produced was found to be proportional to the initial concentration of detergent active matter. A given volume of foam contained approximately the same amount of active agent (4.5 g of active agent as Manoxol O.T. per cubic meter of foam) irrespective of the liquid from which the foam was produced. A routine test designed to measure the foaming tendencies of liquids containing 0 to 8 mg/l active matter was devised. The height of foam is measured after 8 min aeration at the rate of 90 ml of air per min at a pressure of 4 lb/sq in.

Roberts and Lawson (106) developed a method for estimating the concentration of synthetic detergents in sewage sludge. The liquid sludge was centrifuged, dried, and passed through a 100-mesh sieve. The detergent was extracted with methanol in a soxhlet apparatus and determined by methylene blue method. It was

found that digested sludge may contain more than 1 per cent of its dug matter as synthetic detergent. At the Luton Sewage Works all of the synthetic detergent removed by sedimentation was recovered from the settled solids. About 50 per cent of the detergent removed during partial treatment by adsorbing activated sludge was recovered from the sludge. Subsequent passage through an actively nitrifying trickling filter resulted in possible oxidation of 90 per cent of the detergent entering the unit. The detergent was not biologically decomposed during anaerobic digestion.

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Lagooning

Hermann and Gloyna's 3-section report on their inclusive study of stabilization ponds, gives a large volume of detail information on laboratory, pilot plant, and investigation of actual practice based on numerous field reports.

Part I (56) details the results of non-controlled and controlled aquarium experiments, in which the food, temperature, illumination, and wind action could be controlled and noted. Studies of algae population, BOD reduction, DO, and solids increase or reduction were made and correlated. The information derived was used in conducting similar pilot-plant studies outside the laboratory.

Part II (57) is a study of stabilization ponds in Texas, based on records of the State Health Department. The wealth of data accumulated was statistically analyzed.

Part III (58) makes use of the information derived from laboratory and pilot-plant studies, correlated with the results of the analyses of Part II, to develop design factors based on the fundamental van't Hoff-Arrhenius equation. Formulas for design of waste stabilization ponds, their area, depth, and operation, based on loading, light, and temperature conditions of the location, were developed. The authors' premise that bacteria are mainly responsible for organic destruction, emphasizes the effect of temperature; the algae, dependent mainly on the amount of illumination, serve to remove the carbon dioxide produced by this bacterial activity. The proper relation of bacterial and algal population is important, as excess algal population may impose a heavy BOD load.

A comprehensive review of stabilization pond practice both in this country and Europe has been made by Fitzgerald and Rohlich (34). Detailed attention in their report is given to depth, illumination, types of algae, and removal of mineral, bacterial, and organic contents of the sewage entering the pools. Much of this information is given in specific detail. Additional information is made available by a bibliography of over 70 references.

A review of stabilization pond practice in South Dakota, with special attention to climatic conditions, is given by Kalda (69). He states that these ponds will have an ice cover from December 1 to March 15, and that the needed period of recovery from the anaerobic to the aerobic state must be

compensated for by a depth of 5 ft as compared to the usual 3 ft and a BOD load of 35 lb instead of 50 lb; that is, a per capita loading of 100 per acre. No odor nuisance need be feared if these conditions are observed. If the receiving stream requires a higher than the usual purification, two or more ponds in parallel are recommended. The construction cost will be about $20.00 per capita connected, and the land cost about $4.70 per capita.

In comparison to the Dakota conditions, a report on Mississippi requirements, given by Gerber (39), describes a 1-acre lagoon built for a small community of 200 people, with an expected BOD load of 35 lb/acre. The actual loading at the time of the report varied from 25 to 32 lb BOD. The BOD reduction ranges from 244 mg/l in the influent to 44 mg/l in the effluent. The *B. coli* reduction ranges from 99.96 to 99.99 per cent. It is remarkable that even during the wet season combined evaporation and seepage were as high as 40 to 60 per cent. The cost of construction of the lagoon was $28.76 per capita. Another, larger, but similar installation, 15 acres in area, cost $10.28 per capita. Since October 1956 seven such ponds have been put in operation and eight others are partially completed.

Sewage lagooning is being generally accepted as a reliable, effective, and relatively inexpensive treatment method for domestic wastes from small urban areas. This is from the synopsis of a report by the Sanitary Engineering Division of the American Society of Civil Engineers, as made by the chairman R. H. Bogan (15). He adds that data sufficient for design have been accumulated. Tabulations of a number of operational results are given in the report.

Lagooning for the purpose of algae growth as a source of food, has given rise to the necessity of removal of algae from the water. Similarly, an over-abundant growth of algae has caused difficulty in disposing of effluent in bodies of water. The University of California (5) at Concord, California, is experimenting with removal of algae from the water by means of a centrifuge. Feed rates from 100 to 400 gpm have been attained. This project includes study of the use of light energy, employing algae in a digester tube, and conversion of two per cent of the light into fuel has been obtained. A report covering the last three years of this project is in preparation.

Sewage Reuse

Peter (98) reports that the primary effluent from a number of sewage treatment plants in Israel is pumped to a 55-acre sand dune at the rate of 2,000 to 2,500 gpd/acre. This dune is underlain by sandy loam at a depth of 13 to 23 ft. The annual rainfall is 20 in. Cattle fodder is grown and a good humus layer forms during the first year of cultivation. This practice helps to stabilize the shifting sands. A natural depression is used as an experimental percolation area. Sewage effluent is applied at the rate of 85,000 to 100,000 gpd/acre, ten times the agricultural irrigation rate. This raises the water table and prevents salt water intrusion.

According to Merz (89), sewage plant effluent finds ever-increasing use in California. Settled sewage from Santa Ana irrigates 2,250 acres growing alfalfa and sugar beets, and, on a pre-irrigation basis, dry lima beans and chili peppers. This effluent is high in dissolved solids but is considered to be better than the available ground water. The cost is $5.00 per acre-ft to the irrigators. The San Bernardino plant also sells its effluent for irrigation, but will not renew the current contract after expiration. Instead, San Bernardino intends to improve the treatment process and then use this improved effluent for recharg-

ing the groundwater strata. The Golden Gate Park uses 750,000 gpd of the San Francisco treatment plant effluent. After the contemplated plant improvements, 5 mgd will be available for irrigation. Part of this will be for sale at $1 per day per acre. Oceanside will use oxidation ponds for final treatment to prepare the effluent for commercial and irrigation use. A Marine Corps base in the Imperial Valley pays $55 per acre-ft for water piped in from 15 miles away. After reclaiming its sewage plant by pond treatment and using it for irrigation and flushing, the annual savings will amount to $24,000.

Dye (30) reviews the practice in crop irrigation with sewage plant effluent. He quotes the Texas State Department of Health regulations. These forbid use of untreated sewage for any crop, but permit use of primary effluent for animal feed crops and pasture. All public health hazards, nuisances, or stream pollution must be avoided. These regulations also state that reasonable care in using sewage effluent will not endanger the health of personnel. Most western states concur with these regulations. It is noted that California permits the use of properly treated and disinfected sewage that meets the bacterial standards for drinking water to be used for any types of irrigation. The author stresses the fertilizing value of sewage, especially to western soils which are ordinarily low in organic materials. An evaluation of the Tucson sewage plant effluent in that regard is given.

As Dye emphasizes the value of the organic content of sewage, Stone and Merrell (124) consider the mineral content of sewage plant effluent in reference to irrigation and industrial reuse. The report has tabulations of the mineral content of a large number of California and out-of-state treatment plants, together with similar analyses of the original water. These analyses are compared to USPHS drinking water standards and USDA standards for irrigation water. The reasons for the increase in mineral content are discussed, as well as the influence of these increases on the future use of the water, either for irrigation or industry. The possibility of and methods for reconditioning of wastewater for future use are discussed.

From Eastern Europe there are two reports (14) (144) on the effects of fertilizers on soil. The N content of sewage is given as 667 lb/mil gal, the P_2O_5 content as 167 lb/mil gal, and the K_2O content as 501 lb/mil gal. Irrigation with sewage increased the hay yield as much as 300 to 400 per cent, yield of cereals 20 to 50 per cent, and root crops 100 per cent. The protein content of the hay was increased by 6 to 7 per cent. A hay meadow having a deep alluvial soil responded with an increased yield directly corresponding to the volume of sewage applied. The yield was from 5 to 6 times that from a similar plot of ground not under irrigation. The number of bacteria of the surface soil was materially increased.

The possibility of sewage or sewage plant effluent entering underground reservoirs of domestic supplies has been considered (131). No such effluent is being directly used for recharge, but its application to the land and the possible travel of microorganisms has been studied. A California study (79) shows that pollutant bacteria travel a maximum of 100 ft in the direction of normal water movement. An occasional chlorine injection will counteract such pollution. It is interesting to note the investigation of the Hyperion Sewage Treatment Plant of Los Angeles, in a study of such recharging of underground strata by using part or all of its highly treated effluent. Laverty (82) gives a well illustrated description of the methods in this study of the possibilities of

such a recharge, including the treatment required and the underground soil strata structure.

Sullivan (127) discusses further the use of sewage treatment plant effluent for cooling and boiler make-up in a butadiene plant at Odessa, Texas. The phosphate and residual detergent content of the Odessa sewage treatment plant effluent added to the high hardness and solids of the city water necessitated the development of elaborate systems of treatment. The results of laboratory and pilot-plant scale studies by Sullivan envisioned treatment as follows: (a) for cooling water and for make-up in low pressure boilers, cold excess lime and alum, sand filtration plus split sodium and hydrogen zeolite treatment to give desired additional softening, reduction in alkalinity and solids, and control of pH; (b) for feedwater in boilers of higher pressure, a similar but hot system to be applied, using excess lime-soda, sodium aluminate, hot filtration, and hot sodium and hydrogen zeolite treatment.

An unusual report of reuse of sewage plant effluent for replenishing a domestic supply is given by Metzler *et al.* (90). The Chanute incident and resulting study may be credited to the water reuse experience and report to date. Chanute, Kansas, takes its water supply from a 20- to 30-day storage basin formed by a dam across the Neosho River. The prolonged drought of 1952–1957 forced the city authorities to permit the effluent from their sewage treatment plant to flow into the storage reservoir at a point farthest from the water treatment plant intake. The sewage plant effluent had consistently shown a *B. coli* count lower than the Neosho River water. This report reviews the difficulties encountered and the changes made in operation, both at the water and at the sewage treatment plant, with valuable records of chemical and microbiological tests. Results of the investigations and studies are shown in numerous graphs, diagrams, and tabulations. The operation was closely supervised and is well documented so that valuable conclusions can be drawn.

In the discussion of this Report, Connell (90) draws attention to the fact that a long accepted standard is maintained, that is, there will be no water-borne epidemic if sufficient chlorination, coagulation, sedimentation, and filtration are applied so as to reduce the coliforms consistently to fewer than 1 per 100 ml. However, he also points out that the occasional appearance of free-living amoeba and their cysts, and large numbers of other non-pathogenic micro-organisms, indicate a need for re-evaluation of conventional water treatment processes. It is suggested that a "price cannot be placed on safe water," therefore that an attainable margin of safety and improved water acceptability might have justified application of free residual chlorination.

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32nd ANNUAL MEETING

FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

Dallas, Texas — Statler Hilton Hotel

October 12–15, 1959 — Dallas Memorial Auditorium

Sewage Works

DETERMINATION OF SEWER RATES *

By Francis T. Osborne

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Several years ago the subject of sewer rates and their determination was given considerable study by a qualified group of experts. That diversified group was made up from members of the American Society of Civil Engineers, Municipal Section of the American Bar Association, American Water Works Association, Federation of Sewage and Industrial Wastes Associations, National Association of Utility Commissioners, Municipal Finance Officers Association, Investment Bankers Association, and American Public Works Association. This committee and its study was authorized by the several organizations since at that time it was generally agreed that, with but rare exception, utility rates and rate structures were basically unsound.

After a long and exhaustive study the committee issued an excellent report clarifying the problems and outlining a sound basis for future rate studies (1). Unfortunately, this work has been little considered by rate-making authorities. Rates are still being determined on the old "hit-or-miss" basis. The criteria still seem to be, "What are neighboring communities paying?" "How much money do we need per year to finance our improvement? (let's divide that by the number of customers)." "How much a front foot will the property owners hold still for? (that's how much we can spend)." "Our bond buyer only likes Revenue Bonds so that's the way we'll finance and we'll base our rates accordingly." "We've got so much money in reserve and will spend that and just extend our present rates to the new area." "Let's put in a rate of so much per month and then the engineers will just have to live within the money available." These are the usual approaches and, obviously, the resulting rates and rate structures can be anything but fair and equitable.

The approach to the problem of determining fair and equitable rates was spelled out briefly and clearly by the joint committee as follows: "The needed total annual revenue of a sewage utility shall be contributed by 'users' and 'non-users' (users and properties) for whose use, need and benefit the facilities of the works are provided approximately in proportion to the cost of providing the 'use' and the 'benefits' of the works."

It is most important to remember that part of this statement as it relates to the words "use" and "benefit." These are the key to the determination of any fair and equitable rate schedule.

The Sewer Utility

The sewage works facility in a community consists of a variety of structures and appurtenances to collect, treat, and dispose of the spent water

* Presented at the 1958 Annual Meeting, Pacific Northwest Sewage and Industrial Wastes Assn.; Spokane, Wash.; Sept. 25–27, 1958.

of the community. In some cases it serves a further purpose of collecting and disposing of storm water and in still other cases, the ground water. Where the ground water removal is provided for, it infers that specially designed facilities to accomplish this have been provided rather than that the ground water has inadvertently entered the system as a result of inferior workmanship or materials. Each part of the over-all system is designed to do a special service or effect a certain relief. Certain parts of the works are designed and built with excess capacity over immediate demands to provide for future drainage as well as future users. Obviously, the costs of this added capacity are not caused by the users but by the properties and that division should be recognized in determining an allocation of costs.

The basic functions of the sewer utility are as follows:

1. The sewer system which collects and removes discharged wastes from the domestic, commercial, and industrial users. This system provides surface drainage in some combined systems and may provide subsurface or ground water drainage.

2. The treatment and disposal works which removes, destroys, and disposes of objectionable material, and further revives the "spent" water to permit its safe or acceptable disposal in receiving streams or on public lands.

3. The combined parts, in general, safeguard private and public health and welfare; provide for security and development of property both for within as well as outside the corporate limits; may render a direct service in the removal and treatment of industrial wastes which vary in composition and in effect on costs of the overall works; remove certain solid wastes in the form of ground garbage in increasing amounts each year; collects and disposes of spent waters from air condition devices; and, finally, protects the community against damage claims by riparian owners.

From this description of the works and their separate functions it should be readily apparent that there are definite benefits to users and to properties. Obviously, certain portions of the works operate to provide a benefit for which payment on an area basis should be made. While others render a benefit to the users of the facilities for which payment on a basis which measures use—either volume or strength or both—is proper. To cite the extremes would be to show that the service connection serves the user alone while the general structures of the treatment plant and outfall serve the area as a whole. Intermediate and special structures, pipes, and devices may serve more or less limited areas.

Cost Considerations

Costs of construction and operation of certain parts of the works are affected differently by volume and strength of the liquid wastes. Thus, the service which particular users and properties receive should be evaluated in relation to those influences. For example, at the treatment works the sedimentation tanks are influenced both by volume and settling characteristics of the solids, the filters or oxidizing processes by organic loadings, and the digesters and other devices related to treating the sludge are affected by the solids in the sewage.

The costs of constructing and operating the sewage utility may be financed by one or more of several methods provided for by state statutes and by other means to better allocate the costs between the two classes enjoying the benefits, namely users and properties.

Financing Methods

The first consideration should be the allocation of that part of the cost resulting from benefits to properties.

This allocation would be in the form of a local improvement district for towns and cities and as a utility local improvement district for sewer districts. When such assessments are made for new construction they will result in a reduction in the expenditure of utility funds or in repayment of such a fund created by borrowing. The resulting lower base rate permits a reduction in the cost allocation to the users.

A second portion of the cost may be financed by the sale of revenue bonds which by necessity in most states must be repaid by the users only.

A third possibility is the sale of general obligation bonds which would be repaid from tax revenues on properties. This method may be used to assess the cost of benefits directly enjoyed by properties and in some instances reflects benefits enjoyed by users as a result of higher assessed values in the improved or occupied properties.

A final source of financing currently much in evidence is federal aid through grants under Public Law 660. A study of this grant program indicates basic relief to cost of that part of the project which generally benefits the community as a whole and in most instances indicates a reduction in the balance to be allocated to properties rather than users.

Construction and Operation Money

The total moneys needed to construct and operate a utility may be divided into six distinct categories.

1. Operation and maintenance expenses. These include labor, expendable supplies, equipment, supervisory overhead.

2. Depreciation. The establishment of a reserve from which major repairs and/or replacements in kind can be financed.

3. Taxes. These include both excise to higher governmental bodies, for example, the state; and the payment to the municipality or to the county a sum in lieu of tax for franchises and other benefits.

4. Interest on indebtedness. This becomes applicable under only the revenue type financing as interest on either Local Improvement District or General Obligation Bonds and becomes immediately a cost to the property being assessed.

5. Amortization funds. These are generally considered as a part of the revenue bond type of financing.

6. Additional funds. A reasonable return on the investment should be earned. This would in the case of a private utility be termed profit. The public utility should likewise be able to show a profit or reasonable return so that it may appear in the eyes of future bond buyers a desirable investment and thereby command lower interest rates.

Rate Schedule Categories

Present practices in attempts to raise these funds through rate schedules fall generally into six basic categories, within which there is the complete range of variation from religion preference of the mother's user, to the color of the plumbing fixtures. Nevertheless, the six basic categories are these:

Uniform Rates

These have been the simplest and easiest to establish. Under this method an attempt generally has been made to spread the cost uniformly but the charges seem to have been determined by merely setting a rate sufficient to produce the required amount of revenue. As a result the charges do not represent the amount to be paid for either the actual or the presumptive use of the sewage works, therefore these charges are unfair. The only attractive feature of this basic rate schedule is its simplicity. Its use is usually restricted to smaller communities.

Number and Size of Sewer Connections

This method is usually in error in that it is based on the fact that a property with more than one sewer connection offers presumptive evidence of a greater use of the utility. Likewise, rates may also be varied with the size of the sewer connection and a multiple family building may be charged more than a single family building even though there is one separate sewer connection. The use of this type of schedule is likewise generally restricted to smaller communities where important differences among properties are not prevalent.

Type of Property Served

This method is usually based on the presumption that the size and kind of the property or structure thereon reflects the use that will be made of the utility. Where this determination of rate is used, the community rarely classifies the properties into over seven or eight categories and again it is obvious that the results could be nothing less than unfair.

Details of Plumbing Fixtures

This method is often popular in a community where the water works is privately owned, or where water meters are not installed, or where it seems desirable to favor the economically poorer classes of users. It is true that this base may roughly measure the use of the works, but its administration requires a frequent and costly inspection to insure complete and accurate billing. Its inadequacies and inaccuracies can be easily proven to show that the rates evolved may often be unfair.

Water Consumption

Perhaps this method represents the most accurate measure of the relative use of the sewage works and, in general, it results in a fair distribution of the use portion of the total annual revenue. The use of this method, however, is generally limited to an entirely metered water works which is publicly owned and gives no consideration to producing a revenue for those parts of the utility as are necessitated from the organic and solid loadings in sewage.

This basic method should be considered further as it is broken into four different application methods. The first is directly related to the metered water charges, which represents the most accurate measure relative to the use of the sewage works; however, there are inaccuracies and inequities introduced when all of the water used or metered is not discharged into the sanitary sewers, particularly in those areas when appreciable amounts of that water are used for lawn irrigation. This method, then, when used without appropriate adjustment is open to objection and as a result can give rise to much complaint and can result in arbitrary adjustments and eventually a rate schedule that is completely out of balance.

The second alternate under the water consumption base is one that combines both the sewage and water charges under one total amount on the statement. That is, the total earnings from a single statement for combined services should suffice to operate both the water and sewer utilities. This plan has no advantage except simplification of billing procedure and any and all of the inadequacies listed previously can creep in.

The third alternate under the water consumption method is a charge as based on metered water and strength of sewage. This comes closer to a fair distribution of cost; however, it takes a large amount of study and the rate base should be prepared by individuals completely familiar with the utility.

The fourth and final alternate under this is one based on a fixed percentage of the water bill to cover the sewage

charges. This method is perhaps the most common of all the types under the water consumption theory. In this method the billing procedure is simple and inexpensive and the plan can include all water users whether the water service is metered or not. The method does, however, carry over any unfairness that is inherent in water rate schedules.

Quantity of Sewage

This is probably the most fair as it relates to the use of the sewage works but as yet there is no evidence of a sewage meter which will accurately measure any and all sewage flow ranges. Thus, the application becomes most difficult.

Discussion of Rate Schedules

In summing up the six basic methods of fixing rate schedules, it is apparent that in many cases the rates do not reflect the cost of construction, the cost of maintenance and operation, nor the effectiveness of the sewage works. None of them can be fairly determined to comply with the fundamental principle that "the needed total annual revenue of a sewage works shall be contributed by users and non-users (or by users and properties) for whose use, need, and benefit facilities are provided approximately in proportion to the cost of providing the use and the benefits of the works."

Recommended Method of Determining Rates

At this point it is desirable to recommend a method for determining a rate structure that would embody the fundamental principle of determining that the needed total annual revenue which shall be contributed by users and non-users, in accordance with the benefits derived. An important point, however, should be made that no rate structure or method of determining the same should be rigid and final, that differences in local conditions and objectives are so important that any recommended procedure should be sufficiently flexible to permit its use without violence to the fundamental principle, and that it should be adjustable to a wide variety of circumstances. Any rate structure so determined should be periodically reviewed and adjusted where inadequacies or inaccuracies are determined.

This procedure requires a computation of the parts of the needed total annual revenue or costs which are caused on the one hand by the users and the other hand by the non-users or properties.

The procedure for computing fair rates and rate structures is based on the assumption that the fair value of the works and the fair total annual revenue have been readily and clearly established. Where the system is being entirely constructed new, then the fair cost or fair value can be determined readily. Where the rate structure is to cover either a partially existing system and additions thereto, or where it is to cover a completely existing system, then there shall be a careful evaluation of the works to arrive at the fair value.

Once this fair value of the works has been determined, then the total annual cost of each part or function of that works which is attributable to the users on the one hand and non-users or properties on the other hand may be established. This is a direct application of the fundamental principle that the needed total annual revenue shall be contributed by users and non-users in proportion to the cost of providing for the use made by users and for the benefits received by non-users. The object of this computation would be to determine the allocation of the annual amounts on which the rates and rate structure would be based. Thus, one part of the needed total annual revenue will be found to be a fair share of users, and the rates

for computing individual bills to users will be set to yield this amount. The other part will be the fair share to be contributed by non-users, and the charges to property will be set to yield that amount.

Value, Use, and Benefits

The first step would be to prepare a descriptive list of each major part of the utility and the second would be to determine the fair value of each part. The third step would be to divide the amount representing the cost of each major part of the public works into an amount attributable to use and another attributable to benefits to the property. In this procedure, account must be taken of the effect of the source, quantity, and character of the sewage on the value and on the annual cost of each major part or function of the utility. Thus, the cost of sludge disposal facilities is caused mainly by the solids discharged to the works by users and should, therefore, be allocated mainly to use. The size and cost of collecting and intercepting sewers are determined by the quantity of sewage. Their cost can thus be allowed or allocated to use and property in proportion to the quantity of sewage each discharges or contributes to the utility. For example, a typical estimate may reveal that in trunk sewers of a combined system 33 per cent of the capacity will generally result from users, whereas properties might contribute through storm water and infiltration up to 42 per cent, and the remaining 25 could be allocated to future growth. In this determination, then, 33 per cent of the accepted fair value would be caused by the users and should be paid by them. The remainder should be paid for by the properties.

The fair value of each pumping station is allocated between structure and equipment. The structures provide for a longer future than does the equipment and, therefore, the allocation to property is proportionately larger for the structures than for the equipment. Otherwise, the percentages for users are based mainly on quantities with due regard for that part of the cost of screens, screenings disposal facilities in the case of storm waters, and to a wearing on the pumps by grit from storm waters.

In the treatment plant the percentages caused by users and by property depend on both the quantity and the characteristics of the sewage. Therefore, a study of the costs of the various parts of each major part or function is required. Likewise, a percentage of the annual cost of operation of each major part of the plant or of the utility as a whole caused by use and caused by property should be determined.

Use and Property Shares

The next step is a computation of a fair distribution of the use share to each user or group of users. There are two principal classes of users. The first includes residential and commercial users and the second are the industrial users. The fair part of the use share which each should contribute depends on the amount of the use share which is caused by the wastewater quantity and also by the internal characteristics of the wastewater (suspended solids, the chlorine demand, and, where biological treatment is used, probably the BOD).

The computation involves a division of the users' share, first of the fair value and second of the total annual cost into amounts caused by each of the foregoing items. The allocation of the fair value is made to determine the allocation of the fixed charges. All of the fair value of the collecting sewers is considered to be caused by and hence chargeable to quantity. Of the operating cost of the operating sewers 50 per cent is estimated to be caused by quantity of the sewage and 50 per cent by the suspended solids.

This percentage determination is arbitrary and may vary 10 per cent either way in the community under consideration.

For both the capital and the operating costs of sludge disposal facilities, 100 per cent is normally estimated to be caused by the suspended solids and similarly 100 per cent of the chlorinating facility costs are caused by the chlorine demand. In a typical case, then, the average division of that part of the annual cost attributable to the users can be broken into these units: for sewage quantity, 43 per cent, for suspended solids, 46 per cent, and for chlorine demand, 11 per cent.

The average unit rates for use can now be computed by dividing these divisions of use share of the total annual cost by the annual quantities of each item.

The rates for property may be based on area or frontage of the different kinds of property or on some other property yardstick. In the event the amount alloted to non-users or properties is subdivided into the amount caused by developed and that caused by undeveloped property, another base can be determined to establish the rates for non-users.

Rate Structure Formulation

After the average rates for use and for benefits to property have been computed, the next step is the arrangement of these two average rates into rate structures. The rate or charge for use is often computed and billed on the basis of metered quantity of water. If a fair rate structure for water used or consumed is in effect, then the rates and the rate structure for sewage may be computed as a percentage of the metered water bill. Otherwise, a rate structure for sewage should be established.

If a sewage rate structure is established, it is suggested that consideration be given the so-called demand and commodity elements of the things provided by the utility. Based on all of the foregoing, a computation of an average rate for use could be determined as follows:

1. Assume a family of four is contributing 125 gpd/cap, or a total of 500 gpd, the annual quantity for the family is 182,500 gal.
2. Assume that collections will be about 95 per cent of the amount billed.
3. The previously determined rate per 1,000 gal will then be applicable and thus the average annual payment by a family or domestic dwelling will have been determined for the quantity portion.
4. Assume that each member of the family would contribute 0.2 lb/day of suspended solids and would be responsible for 0.01 lb/day chlorine demand.
5. The annual charge or contribution per family for these characteristics may then be determined and applied to the previous unit cost for the handling of solids and chlorine demand.
6. Thus, a basic annual unit cost is determined for the use portion as well as for the non-user or property contribution in retiring the debt, establishing the reserves, and paying for the general overhead and operation costs.

Reference

1. Joint Committee Report, "Fundamental Considerations in Rates and Rate Structures for Water and Sewage Works." *Ohio State Law Jour.*, **12**, 151 (1951).

BACTERIAL DEGRADATION OF ABS

I. FUNDAMENTAL BIOCHEMISTRY *

By Ross E. McKinney and James M. Symons

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Modern technology constantly produces new compounds which make their way into sewage. The most important series of new compounds has been the synthetic detergents which have replaced soaps as the primary cleansing agents. With the increased usage of synthetic detergents there has been an increase in sewage treatment problems which were blamed on the presence of syndets in sewage. A general review of the syndet problems in sewage and sewage effluents has already been made (1). It suffices to say that syndets have been blamed for many of the sewage treatment problems since World War II.

There have been many investigations to determine the exact effect of syndets on activated sludge. Many of these have been carried on since 1952 by Sawyer. A summary of his work was published in 1958 (2).

One phase of Sawyer's research was concerned with the alkyl benzene sulfonates which make up approximately 50 per cent of the syndets produced. His studies showed that commercial alkyl benzene sulfonates were not readily degradable by activated sludge. The failure to degrade the alkyl benzene sulfonates resulted in frothing of such magnitude that it was impossible to maintain the activated sludge under diffused aeration. Special mechanical aerators were required to keep frothing at a minimum. It appeared from Sawyer's studies that the commercial alkyl benzene sulfonates were responsible for many of the problems facing activated sludge plant operators.

In order to ascertain the exact effect of commercial alkyl benzene sulfonates on sewage the Association of American Soap and Glycerine Producers authorized a series of research projects at various universities. One of these projects was established to investigate the fundamental microbiology of ABS metabolism. The premise was made that if the structure of ABS was as shown in Figure 1, bacteria should exist which could degrade the ABS molecule completely.

Fundamental Biochemistry

The structure of ABS can be divided into three component parts: (a) the tetrapropylene side chain, (b) the benzene ring, and (c) the sulfonate group. In order to metabolize the entire ABS molecule it would be necessary for the bacteria to be able to metabolize each

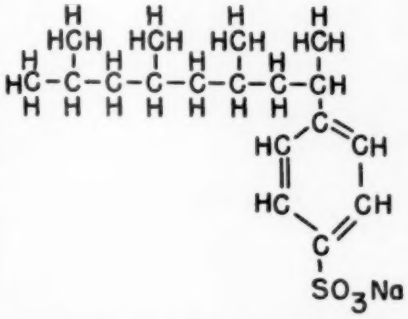

FIGURE 1.—Theoretical structure of alkyl benzene sulfonate.

* Presented at the 31st Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; Detroit, Mich.; Oct. 6–9, 1958.

of the component parts. Examination of the bacteriological literature indicated that bacteria should be able to metabolize the saturated hydrocarbon side chain and the benzene ring. Only the sulfonate group appeared as a potential problem.

Tetrapropylene Side Chain

Porter (3) showed that many common soil bacteria could grow on saturated hydrocarbons. ZoBell (4) found that the branched saturated hydrocarbons could be metabolized as readily as the straight chained hydrocarbons. The end product of hydrocarbon metabolism was an acid which was formed by the oxidation of a terminal methyl group. The fatty acids could then be completely oxidized to carbon dioxide and water. Thus, the tetrapropylene side chain did not appear to offer a major stumbling block in ABS metabolism.

Benzene Ring

Stanier (5) has studied the degradation of the benzene ring by *Pseudomonas*. He found that the benzene ring was split into a six carbon dicarboxylic acid which was oxidized in the same manner as the fatty acids. In this way the metabolism of the hydrocarbon side chain and the benzene ring are metabolically related.

Bacteria have three common amino acids in their protoplasm which are made up of a hydrocarbon side chain and the aromatic ring: (a) phenylalanine, (b) tyrosine, and (c) tryptophan. The structures of these amino acids are shown in Figure 2. Bacteria can both synthesize and degrade these compounds. These facts would indicate that bacteria should be able to degrade alkyl benzene compounds.

Sulfonate Group

Very little is known about the metabolism of the sulfonate group. The major work with the effect of the sulfonate group on bacteria was done with sulfanilamide. Lammana and Mallette (6) have summarized much of the work on sulfanilamide. They indicated that sulfanilamide was toxic to bacteria because it substituted for para-amino benzoic acid, a key intermediate in the synthesis of new protoplasm. Substitution of a methyl group for the amino group on the benzene ring forming toluene sulfonate eliminated the bacteriostatic properties of the sulfanilamide.

Thus, it appeared from the pure bacteriological literature that bacteria existed which could metabolize the component parts of commercial alkyl benzene sulfonates. There was little reason to doubt that bacteria could be found to metabolize the entire molecule.

Isolation of Bacteria

Bacteria which utilized ABS as their sole source of carbon were quickly isolated. The ABS studied was a special composite blend of ABS by the major producers and was furnished by the

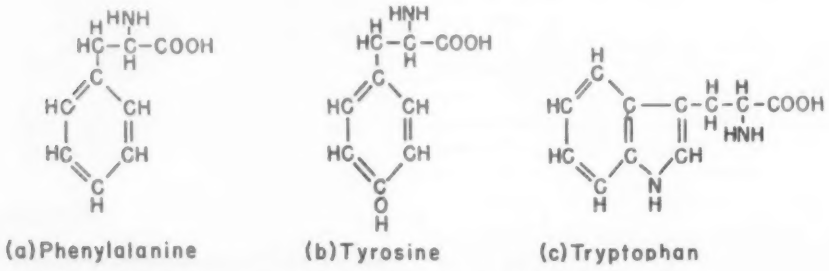

FIGURE 2.—Aromatic amino acids in bacterial protoplasm.

American Association of Soap and Glycerine Producers. In this way the ABS was typical of the mixture found in sewage. The ABS utilizers were isolated from direct growth on special ABS agar plates which consisted of 2,000 mg ABS, 1,300 mg dibasic ammonium phosphate, 15 g of plain agar, and one liter of Cambridge, Mass., tap water. Standard streak plates were made using soil extracts, sewage, and activated sludge as the source of microorganisms. Thirty-four bacteria were isolated in pure culture from the ABS agar.

The identification of the pure cultures was carried out in accordance with the procedures set forth by the Society of American Bacteriologists (7), and with the characteristics found in Bergey *et al.* (8). The identifications of the bacteria are listed below. All of these bacteria are common soil and water bacteria.

Cultures Isolated	No.
Alcaligenes faecalis	7
Alcaligenes viscosus	2
Alcaligenes bookeri	1
Pseudomonas putrefaciens	2
Pseudomonas denitrificans	1
Pseudomonas convexa	1
Pseudomonas (unknown)	11
Flavobacterium suaveolens	1
Escherichia coli	1
Aerobacter aerogenes	3
Paracolobactrum aerogenoides	3
Bacillus (unknown)	1

Growth on ABS Agar

The pure cultures were grown on ABS agar and transferred to new ABS agar plates to insure that growth was due only to ABS metabolism. Of the original 34 cultures, 15 cultures showed good to excellent growth. These cultures were transferred to a broth medium containing 1,000 mg/l ABS and nutrient salts. After four days' incubation, streak plates were made again on ABS agar from each tube. Seven of the 15 cultures showed good growth indicating that the 1,000 mg/l ABS was not toxic to all of the bacteria.

Synthetic Sewage

Bacteria in nature must grow on ABS in the presence of other organic matter. In order to determine what the bacteria will do in relationship to a mixed substrate, a synthetic sewage made up of 150 mg/l nutrient broth and 150 mg/l glucose in Cambridge, Massachusetts, tap water. A series of ABS concentrations were made up to give a final ABS concentration in the synthetic sewage of 0, 6, 15, 30, 60, 150, 300, and 600 mg/l. The pure cultures were inoculated into the tubes and incubated 20 hr, at which time the growth was measured by a spectrophotometer. Of the original 34 pure cultures only 21 were sufficiently active to use in this study. Of these 21 cultures, 7 cultures showed the same turbidity in the presence of the ABS as in its absence, 4 cultures showed decreasing turbidity with increasing ABS, and 10 cultures showed greater turbidity in the presence of the ABS.

After an additional 24-hr growth, 11 cultures showed no effect, 7 cultures showed stimulation, and 3 cultures showed toxicity. After 5 days' incubation, 7 cultures showed no effect, 7 cultures showed stimulation, and 7 cultures showed toxicity. It appeared that some of the bacteria were definitely stimulated in the utilization of the synthetic sewage by the ABS while others were unaffected and still others were retarded. It was not possible to determine to what extent the ABS was utilized. Since it appeared that some bacteria could grow on ABS broth alone and in the presence of synthetic sewage, emphasis was shifted from pure cultures to bacterial mixtures which occur in activated sludge.

Activated Sludge

Activated sludge offered definite advantages in studying the microbiological degradation of ABS. In activated sludge the bacteria best able to metabolize the ABS would be automatically

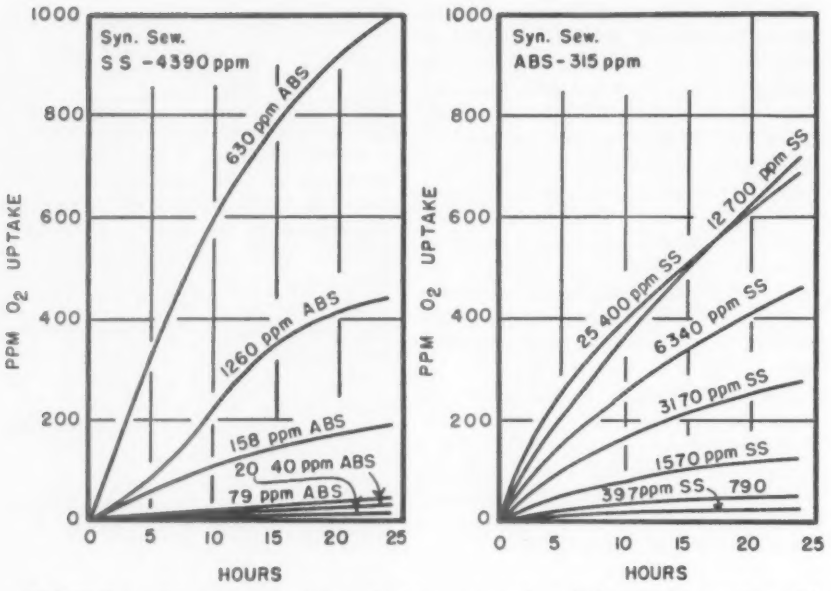

FIGURE 3.—Oxygen uptake by synthetic sewage activated sludge with varying additions of ABS at constant suspended solids and with varying suspended solids at constant addition of ABS.

selected from the mixture of bacteria used in the initial seed. Activated sludge with its flocculating ability permits continuous feeding and an adaptation to the ABS. Since the bacteria in normal activated sludge are the same type as those isolated from the ABS agar studies, there was nothing to be gained from further studies on pure cultures.

Synthetic Sewage

A synthetic sewage was made by mixing the following materials: (a) 300 mg glucose, (b) 300 mg nutrient broth, (c) 300 mg sodium benzoate, (d) 300 mg potassium phosphate, dibasic, and (e) 1.0 l Cambridge, Mass., tap water. The laboratory activated sludge systems were 1.5-l units operated on a 24-hr fill-and-draw basis. The units were started with 500 ml Boston, Massachusetts, domestic sewage and one liter of synthetic sewage. After 48 hr of aeration the air was stopped and the activated sludge was allowed to settle. One liter of settled supernatant liquor was removed and replaced with one liter of synthetic sewage. The air was started again. After 23 hr of aeration, the sludge was allowed to settle for one hour. The units were fed fresh synthetic sewage. Within three weeks, the mixed liquor suspended solids were built up to 4,390 mg/l.

Varying ABS

A Warburg run was made using varying ABS concentrations of 0, 20, 40, 79, 158, 630, and 1,260 mg/l. Oxygen uptake readings were made over a 24-hr period. In order to determine the effect of the ABS, the oxygen uptake for the 0 mg/l ABS unit was subtracted from the other units. The oxygen uptake curves are shown in Figure 3.

The oxygen uptake curves showed increased oxygen uptake up to 630 mg/l ABS, while the 1,260 mg/l ABS gave

definite retardation of oxygen uptake. The shape of the oxygen uptake curves did not show typical oxygen uptake for a readily utilizable substrate, indicating that the ABS was not readily assimilated by the bacteria in the activated sludge.

Mixed Liquor Suspended Solids

In order to determine if ABS could be completely metabolized by the activated sludge, another Warburg run was made at 315 mg/l ABS concentration and varying mixed liquor suspended solids concentrations. The mixed liquor suspended solids concentrations were 397, 790, 1,570, 3,170, 6,340, 12,700, and 25,400 mg/l. The oxygen uptake data are plotted in Figure 3. The oxygen uptake of the non-ABS fed sludge was subtracted from the ABS fed sludge to give the oxygen differences due to the ABS.

The oxygen uptake, instead of being relatively constant, was primarily a function of the mixed liquor suspended solids. The shape of the oxygen uptake curves again did not indicate ready utilization of the ABS. It appeared that the ABS reacted with the mixed liquor suspended solids to release oxidizable organics which gave the oxygen uptake.

Adaptation

Although the synthetic sewage activated sludge failed to give complete metabolism, an effort was made to adapt the synthetic sewage activated sludge to 315 mg/l ABS as the sole source of organics. This was done by adding 16 mg/l of ABS and reducing the synthetic sewage $\frac{1}{20}$ on the first day. The ABS concentration was increased to 32 mg/l on the second day and the synthetic sewage was reduced $\frac{1}{10}$. It was proposed to convert the activated sludge from the synthetic sewage to ABS in 20 days. Before the ABS concentration reached 96 mg/l, however, foaming had blown most of the suspended solids out of the aeration unit. It appeared that the ABS was not completely metabolized and that it was not possible to operate an activated sludge system on ABS alone.

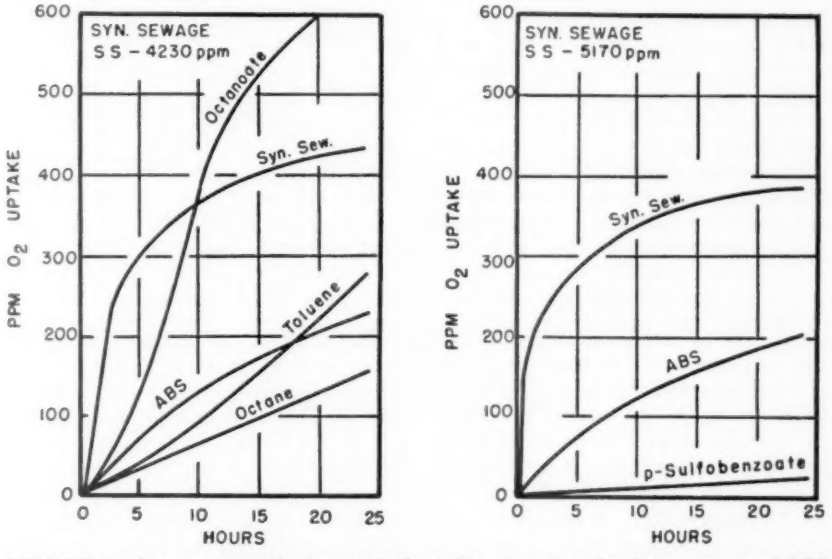

FIGURE 4.—Oxygen uptake in the metabolism of structurally related components of ABS by synthetic sewage activated sludge.

Component Metabolism

In order to determine where the metabolic problem lay, a Warburg run was made with 500 mg/l octane, octanoate, and toluene. The synthetic sewage was included to show how the adapted substrate was metabolized. ABS was included at 315 mg/l concentration. The results are shown in Figure 4. The synthetic sewage was metabolized quite rapidly with 35 per cent theoretical oxidation in 24 hr. The ABS showed a reduced but definite oxygen utilization with 28 per cent theoretical oxidation. Octanoate showed adaptive metabolism. The insoluble octane was slowly metabolized while toluene showed a little more rapid adaptation. The metabolism of these compounds indicated that while solubility retarded metabolism, the activated sludge could metabolize a long chain fatty acid. Since the synthetic sewage contained a benzene ring compound, the problem in metabolism did not appear to be related to the hydrocarbon side chain or to the aromatic ring.

A second Warburg run was made using *p*-sulfobenzoate to determine the effect of the sulfonate group. The *p*-sulfobenzoate was run at 500 mg/l. Synthetic sewage and ABS at the previous concentrations were run as a check on the activated sludge. The results are shown in Figure 4. The synthetic sewage had 32 per cent theoretical oxidation while the ABS gave 30 per cent. The *p*-sulfobenzoate definitely showed retarded metabolism.

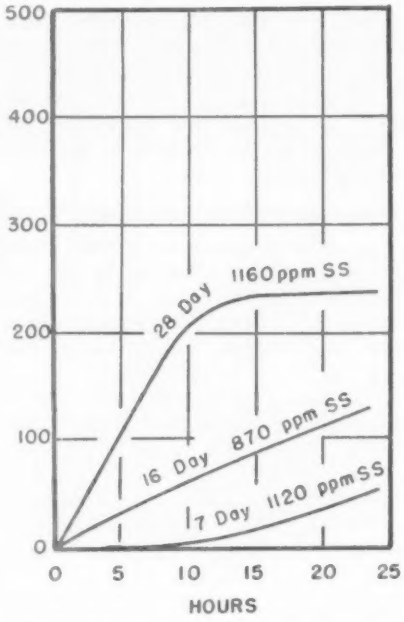

FIGURE 5.—Oxygen uptake by *p*-sulfobenzoate activated sludge during adaptation period.

p-Sulfobenzoate

In order to determine if it were possible to adapt to *p*-sulfobenzoate, an activated sludge was fed 500 mg/l *p*-sulfobenzoate daily. Analyses of mixed liquor suspended solids were made daily to determine the change in solids which would be a measure of utilization of the *p*-sulfobenzoate. Suspended solids started at 1,570 mg/l and fell to a minimum of 780 mg/l after 13 days, then rose to 1,120 mg/l after 44 days. Warburg runs were made on the 7th, 16th, and 28th days. The oxygen uptake curves are plotted in Figure 5. The activated sludge slowly adapted to the *p*-sulfobenzoate and was completely degrading it by the 28th day of the run. Thus, it appeared that the microorganisms in activated sludge could adapt to the sulfonate group although the mixture retarded metabolism initially.

ABS Structure

The question of metabolism of the component parts of ABS but not the complete structure was a very difficult one unless the structure of ABS was not as indicated. Just as the question of metabolism arose, Continental Oil Company (9) issued a report indicating their alkylate yielded a mixture of many compounds, the average formula being the ABS structure shown in Fig-

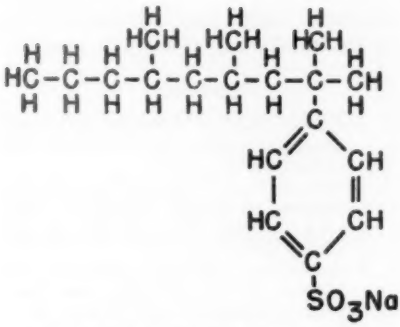

FIGURE 6.—Structure of ABS as reported by Continental Oil Company

ure 6. Examination of this structure immediately pointed to the key difference in the previous structure, the junction of the hydrocarbon side chain to the benzene ring. The presence of a quaternary carbon at this point indicated a potential block based on fundamental metabolism. Analysis of the structure of the alkylate under study yielded essentially the same structure.

The lack of a hydrogen or a hydrogen replaceable group in the quaternary carbon would theoretically block bacterial metabolism at this point. Thus, partial oxidation would occur until the block was reached. Further metabolism would be limited to displacement of the blocked material from the cells and the normal substrate end product equilibrium.

Alkyl Benzenes

Sawyer and Ryckman (10) began a systematic study of pure alkyl benzene sulfonates to determine if structure was the key to metabolism. They found that both primary and secondary alkyl benzene sulfonates could be biologically degraded but that the tertiary alkyl benzene sulfonates, those containing the quaternary carbon, were not. These data were confirmed by a long term Warburg run on a homologous series of alkyl benzene compounds up to the amyl benzenes. The t-butyl and t-amyl benzene compounds showed reduced metabolism over the other compounds. Thus, it appeared that the major problem lay in the structure of the ABS.

Discussion

The metabolism of organic matter by activated sludge follows a definite pattern. With ABS it is believed that metabolism starts with the terminal methyl group on the hydrocarbon side chain. The terminal methyl group is oxidized by enzymes to a carboxyl group. From this point the hydrocarbon side chain is metabolized by beta oxidation until it reaches the quaternary carbon. The quaternary carbon prevents further oxidation and thereby blocks metabolism.

The concept of a quaternary carbon block is based on the mechanism of hydrogen removal from organic matter. Inside the microorganism enzymes remove two hydrogen atoms at a time and oxidize them to water. These hydrogen atoms are removed in pairs from adjacent carbon atoms. With the quaternary carbon there is no hydrogen to be removed so that metabolism stops at this point (Figure 7). The ABS and the enzyme are bound together in a complex and so remain. This means that unless more enzymes are made, the ABS metabolism will cease and free ABS will remain in solution.

The data of Sawyer and Ryckman (10) definitely confirms the soundness of the concept of the quaternary block. If the ABS did not contain this quaternary carbon, the microorganisms in activated sludge would have little difficulty in metabolizing the syndet, for the common water and soil bacteria

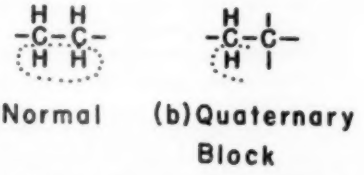

FIGURE 7.—Structure showing removal of hydrogen atoms and the quaternary block.

which predominate in activated sludge have definitely shown the ability to attack ABS.

Conclusions

The following conclusions were drawn from this study:

1. Common soil and water bacteria which predominate in activated sludge can utilize ABS as their sole source of organic matter.
2. Some bacteria can live in the presence of organic matter and ABS.
3. ABS stimulates the utilization of organic matter in some bacteria.
4. Activated sludge cannot completely degrade ABS.
5. Activated sludge can degrade the basic component parts of the ABS molecule.
6. The failure of activated sludge to degrade ABS completely is caused by a quaternary carbon in the hydrocarbon side chain which blocks metabolism.
7. The quaternary carbon is believed to exist where the hydrocarbon side chain joins the benzene ring.

Acknowledgment

The authors wish to acknowledge the financial support of the Association of American Soap and Glycerine Producers which made this study possible.

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DRINKING WATER STANDARDS BEING REVISED

On March 24 and 25 a group of physicians, scientists, engineers, and administrators met in Washington, D. C., to consider revision of the U. S. Public Health Service Drinking Water Standards. In view of changes in the nature and extent of impurities which are being added to the Nation's supplies as a result of greater population growths and even greater technological and industrial development, the Public Health Service has appointed this Advisory Committee to re-evaluate these Standards, which were first formulated 45 years ago and last revised in 1946.

This was the first of a series of meetings scheduled for coming months by the Advisory Committee. The Federation is represented in this group by Professor F. W. Gilcreas of the University of Florida.

SANITARY ASPECTS OF COMPOSTED SEWAGE SLUDGE AND SAWDUST*

By James B. Reeves

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There exists a continuing need and demand for humus and organic plant food. Sewage sludge is one source of humus that has not been fully utilized, even though the use of sludge as a fertilizer is an ancient practice. It was reported (1) that Rafner and Baker in 1894 referred to eight practical methods of sludge disposal. The processes concerned were essentially irrigation with sewage effluent. Since that time sludge has had various applications on plants. It has been used quite extensively in citrus orchards, particularly where the soil is sandy, granular, and needs humus. Although it has been used as a fertilizer for vegetable crops, there is a feeling that its use should be restricted to field and grain crops. Reasons for this belief have their origin in (a) aesthetic objections, (b) objectionable odors, and (c) the fear of spreading pathogenic organisms. The only obvious index of the danger of spreading pathogenic organisms lies in the evidence of experiments to determine the existence of these organisms in sewage or the materials derived from it. The sewage sludge utilization manual (1) quotes Wolman as indicating a survival time of *Salmonella typhosa* † in sewage sludge of up to 365 days. Mom and Schaeffer (2) isolated *Salmonella typhosa* † in fresh digested sludge from an Imhoff tank. They were unable to isolate it from sand sludge drying beds. Ruchhoft (3) was able to isolate the typhoid organism after 83 days in activated sludge at 50 to 72°F. He felt that wet activated sludge could not be considered innocuous. Cram and Hicks (4) in studying the effects of sludge digestion on the ova of *Ascaris lumbricoides* found that they may survive for as long as one year. Cram (5) in studies on the survival of helminth ova showed that hookworm ova could survive as long as 64 days in digested sludge. Cooke and Kabler (6) were able to isolate the potentially pathogenic fungi, *Aspergillus fumigatus* and *Geotrichum candidum* from digested sludge. Heukelekian and Albanese (7) were able to isolate *Mycobacterium tuberculosis* from primary and secondary treated sludges. Wright *et al.* (8) found apparently viable eggs of *Trichuris sp.* in primary and secondary digesters. Tanner (9) in summarizing the public health significance of sludge used as a fertilizer came to the conclusion that fresh vegetables raised on polluted soil may transmit pathogenic bacteria. Muller (10) felt that sludge treatment as usually carried out is insufficient to destroy pathogenic microorganisms including helminth ova. Kelly *et al.* (11) citing existing standards of sewage treatment did not feel that these methods necessarily control disease agents.

* Presented at the 34th Annual Meeting of the Southwestern and Rocky Mountain Division of the American Association for the Advancement of Science; Las Vegas, N. Mex.; Apr. 28, 1958.

† Designated as *Eberthella typhosum* and *B. typhosum* in references.

McCauley (12) found that composting is a satisfactory method of treating organic wastes. Composting sludge with sawdust produces a product which resembles leaf mold in texture, appearance, and odor. Aesthetic objections are rare and the odors which emanate from the wetted compost bear no resemblance to the original constituents. The compost is quite acceptable and offers a relatively simple way for the sewage plant operator to dispose of an otherwise troublesome waste. It is also beneficial to the land and adds moisture to the soil. Ullrich and Smith (13) using digested sludge mixed with hardwood sawdust found that a completed compost could be obtained in approximately 11 weeks.

As indicated by the work carried on by those discussed above, it appeared as though there was a potential solution to an existing problem. If it could be shown that the pathogenic organisms that might be present cannot survive temperatures developed within the compost pile and that the composted sludge could safely be used on private lawns and public parks without danger of spreading pathogenic organisms, then the serious sludge disposal problem could be alleviated. Others (14)(15) have also discussed this subject.

With these facts in mind, a limited survey of a sawdust composted sewage sludge was begun in conjunction with the Public Service Board and sewage treatment plant of the City of El Paso, Texas. The focus of attention in this limited survey was directed primarily to the isolation of the pathogenic intestinal bacteria, principally those of the *Salmonella* and *Shigella* genera.

Experimental Methods and Materials

The composting operation was carried on as follows:

Air-dried sludge was placed in windrows approximately 300 ft in length. The sludge was combined primary and secondary which had been digested for a period of 45 to 90 days, followed by 4 to 6 months on drying beds (Figures 1, 2, and 3). The proximity of residential areas is noted in the background. The compost site is approximately 500 yd from the drying beds.

The sludge windrows were approximately 6 ft wide at the bottom, 4 ft

FIGURE 1.—Sludge drying area used as source of domestic sludge for composting, showing surface water soon after filling with digested sludge.

FIGURE 2.—Sludge loading operation from drying beds in preparation for hauling to composting site.

wide at the top, and 4 ft high. Windrows of hardwood sawdust were placed alongside. Mixing was accomplished by repeated folding over with a road grader (Figure 4). The combination was wetted with city water at two- to three-week intervals and turned with the grader. After two to three months of composting, the material was ground twice with a Royer Shredder (Figure 5), mixed, wetted, and placed in piles approximately 12 ft wide, 16 ft long, and 6 ft high. These piles, shown in the background of Figure 3, were allowed to remain undisturbed for an additional period of two to three months.

The compost was composed of small particles, grayish in color, with a humus-like odor, and with good moisture retaining properties.

FIGURE 3.—Dumping dried sludge to form beginning of compost pile.

FIGURE 4.—Turning operation to mix sludge and sawdust, using a road grader.

Compost samples were taken with a standard soil sampler, four feet in length. Sampling depths varied from 1 to 24 in. There were 4 samples taken at a 2-in. depth, 4 taken at a 4-in. depth, 4 taken at an 8-in. depth, and 1 taken at a 24-in. depth. Samples were taken at 10- to 14-day intervals over a period of 4 months.

The samples of compost were collected in sterilized 600-ml beakers at 1-, 2-, 4-, 8-, and 24-in. depths. The ambient temperatures were taken at the time of sample collection to determine, if possible, whether there would be any correlation between the air temperatures and the pathogenic organisms isolated. A portion of each

FIGURE 5.—Shredding operation at compost site.

sample was examined for coliforms. The "Standard Methods" Presumptive Test was used with inoculation into lauryl tryptose broth, and incubation at 35°C for 24 hr. Presence of gas was taken as presumptive evidence of the presence of coliforms. The membrane filter was also utilized for the isolation of the coliform group. The total bacterial count or population was determined by introducing 1-ml amounts of various dilutions into plate count agar and incubating 24 hr at 35°C.

Moisture content of the compost was estimated by first weighing an appropriate portion of the compost and placing it in a drying oven at 100°C for 24 hr. After drying, the weight of the sample was again determined. The moisture content was then calculated.

The remainder of the sample was handled in the following manner: Two 15-g samples were removed aseptically and placed in 250-ml Erlenmeyer flasks containing 100 ml of Bacto-Selenite "F" broth; two 15-g samples were removed and placed in 250-ml Erlenmeyer flasks containing 100 ml of Bacto-tetrathionate broth; and two 2-g samples were placed in 10-ml amounts of the above enrichment broths. These samples were then incubated for a period of 18 to 24 hr at a temperature of 35°C. At the end of the incubation period, the samples were removed from the incubator and a 4-mm nickel chrome loop was used to streak the sludge enrichment emulsion to six differential and selective agar plate media. These media were (a) Brilliant Green Agar, (b) SS Agar, (c) Bismuth Sulfite Agar, (d) MacConkey's Agar, (e) Desoxycholate Agar, and (f) Desoxycholate-citrate Agar. The streaked plates were incubated at 35°C for a period of 18 to 24 hr. At the end of the incubation period, the plates were removed and examined for the presence of bacterial colonies having the characteristics of the *Salmonellae* and *Shigellae*. These were fished to Triple-Sugar-Iron agar slants. Those showing alkaline slants, acid butts, with or without gas, and hydrogen sulfide were fished to urea broth. Negative urea cultures were retained for further testing. These criteria were selected as representative of the *Salmonellae:*

1. Gram negative bacilli
2. Non-spore forming
3. Motile
4. Biochemical reactions
   - (a) lactose negative
   - (b) sucrose negative
   - (c) salicin negative
   - (d) glucose acid and gas
   - (e) maltose acid and gas
   - (f) rhamnose acid and gas
   - (g) dulcitol acid and gas
   - (h) mannitol acid and gas
   - (i) xylose acid and gas
   - (j) indole negative
   - (k) acetylmethylcarbinol negative

Criteria for the *Shigellae* were as follows:

1. Gram negative bacilli
2. Non-motile
3. Non-spore forming
4. Biochemical reactions
   - (a) acid only from the various carbohydrates and alcohols
   - (b) indole production variable

Results and Discussion

In Table I, the numbers of *Salmonellae* and *Shigellae* are shown in relation to sample depths for 13 samples. This limited sampling indicated the ease of isolating *Salmonellae* and *Shigellae* at depths up to and including 24 in.

Table II compares the moisture content of the composting sewage sludge and sawdust, the ambient temperature, and the pathogens isolated. With the possible exception of the sample containing 10 per cent mois-

TABLE I.—Comparison of Sample Depth and Numbers of Pathogens Isolated from Composted Sewage Sludge and Sawdust

Depth of Sample (in.)	Strains of Pathogenic Intestinal Bacteria Isolated	
	Salmonella (No.)	*Shigella* (No.)
1	0	0
2	28	3
4	17	3
8	10	0
24	6	0

ture, it is difficult to see any correlation between the moisture content and the numbers of *Salmonellae* and *Shigellae* isolated.

Under the conditions as imposed by the short period of time and limited sampling concerned in this preliminary report, the air temperature has little, if any, effect on the ability to isolate these pathogens. However, on the basis of other studies, the ambient temperatures have a direct bearing on the temperatures developed in the composting mixture of sewage sludge and sawdust, particularly on the surface of the windrow. It is generally accepted practice that it is essential for these areas to be properly turned to insure their being subjected to the higher temperatures in the interior. Unfortunately, internal temperatures were not recorded in these tests. Therefore, no specific comparison can be made of internal temperatures and pathogens.

TABLE II.—Effects of Ambient Temperature Moisture Content, and Numbers of Pathogens Isolated from Composted Sewage Sludge and Sawdust

Sample No.	Sample Depth (in.)	Moisture Content (%)	Ambient Temperature* (°F)	Pathogens Isolated	
				Salmonella	*Shigella*
1	2	10	60	0	0
2	2	21	73	3	0
3	2	22	62	0	0
4	2	23	83	3	0
5	4	24	80	14	3
6	4	27	83	3	6
7	4	35	90	13	3
8	4	36	66	4	0
9	8	38	93	3	0
10	8	41	66	9	0
11	8	45	82	0	0
12	8	46	74	4	0
13	24	68	69	4	0

* Obtained from weather bureau at El Paso.

Table III gives the total bacterial count and coliform density in relation to the *Salmonellae* and *Shigellae* iso-

TABLE III.—Relation of Coliform Density, Total Bacteria Count, and Pathogens Isolated from Composted Sewage Sludge and Sawdust

Sample No.	Sample Depth (in.)	Total Bacteria in Compost (No./g)	Coliform Density in 100 g Compost (MPN)	Pathogens Isolated	
				Salmonella	*Shigella*
1	2	—*	0	0	0
2	2	—*	23,000	3	0
3	2	—*	38,000	4	0
4	2	880,000	380,000	0	3
5	4	138,000	360,000	0	0
6	4	2,600,000	6,200	4	0
7	4	20,000	110,000	4	0
8	4	71,000	1,100,000	0	3
9	8	85,000	62,000	0	3
10	8	10,000	23,000	13	0
11	8	—*	1,700	17	0
12	8	65,000	24,000	16	0
13	24	7,000	3,600	0	3

* Colonies too numerous to count.

lated from the compost. In these instances also, there is no apparent relationship.

However, the relative ease with which these groups were isolated on a purely qualitative basis is evidence that there is a potential danger in the use of the material in garden soils and/or on vegetable crops. At the present time, further studies are in progress to determine more fully if there is a correlation in any of these factors relative to obtaining a temperature sufficient to destroy these organisms or to render the material safe for use.

During one phase of this investigation, sewage effluent was used to moisten the composting mixture. A sudden and dramatic increase in the numbers of *Salmonellae* and *Shigellae* was noted, making it obvious that this is a practice which should not be indulged under any circumstances of the composting process.

Summary and Conclusions

The ease with which members of the *Salmonella* and *Shigella* genera were isolated is presumptive evidence of the dangers involved in the possible dissemination of disease through the use of composted sewage sludge as a humus. In this study, 61 strains of the genus *Salmonella* and 12 strains of the genus *Shigella* were isolated in air dried sludge and hardwood sawdust compost. No apparent effects of moisture content, ambient temperature, total plate count, and coliform density were obtainable under the time limit imposed. However, these preliminary studies formed the basis for continuing more detailed work to determine if a practical and economical method of control can be obtained.

Acknowledgments

Gratitude is expressed for the assistance of Mr. Haskell Street, Superintendent of the El Paso water and sewage treatment plants and to the personnel of his staff for the performance of the total plate count, moisture content, and coliform density determinations. Appreciation is also expressed for the helpful suggestions of Dr. A. H. Berkman of Texas Western College.

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MEETINGS OF INTEREST

May 4–8 **American Society of Civil Engineers,** Hotel Cleveland, Cleveland, Ohio. W. H. Wisely, Executive Secretary, 33 West 39th Street, New York 18, N. Y.

May 5–7 **Fourteenth Industrial Waste Conference,** Purdue University, Lafayette, Ind. Professor Don E. Bloodgood, Purdue University, Lafayette, Ind.

May 6–9 **12th International Conference on the Study of Waters,** Cebedeau, Liege, Belgium. Edm. Leclerc, Centre Belge D'Etude et de Documentation Des Eaux, 2, rue Armand Stévart, Liege, Belgium.

May 8 **5th Industrial Hygiene Conference on Health Engineering in the Space Age,** University of Texas, Austin, Tex.

May 11–13 **American Society of Mechanical Engineers,** Chicago, Ill. American Society of Mechanical Engineers, Meetings Dept., 29 West 39th Street, New York 18, N. Y.

May 13–15 **National Rivers and Harbors Congress,** Mayflower Hotel, Washington, D. C. William H. Webb, Executive Vice-President, 1028 Connecticut Avenue, N. W., Washington 6, D. C.

May 17–20 **American Institute of Chemical Engineers,** Muehlebach Hotel, Kansas City, Mo. Raymond C. Mayer and Associates, 51 East 42nd Street, New York 17, N. Y.

May 18–20 **Instrument Society of America,** Shamrock-Hilton Hotel, Houston, Tex. Instrument Society of America, 313 Sixth Avenue, Pittsburgh 22, Pa.

June 8–9 **Industrial Water Conservation,** School of Public Health, University of Michigan, Ann Arbor, Mich.

June 22–26 **Air Pollution Control Association,** Hotel Statler, Los Angeles, Calif. Harry M. Pier, Executive Secretary, Air Pollution Control Association, 4400 Fifth Avenue, Pittsburgh 13, Pa.

June 22–26 **American Society for Testing Materials,** Chalfonte-Haddon Hall, Atlantic City, N. J. Robert J. Painter, 1916 Race Street, Philadelphia 3, Pa.

July 12–17 **American Water Works Association,** Civic Auditorium, San Francisco, Calif. Harry E. Jordan, Secretary, American Water Works Association, 2 Park Avenue, New York 16, N. Y.

Industrial Wastes

WASTES FROM THE PRODUCTION OF REACTOR-GRADE ZIRCONIUM

By R. C. Palange, C. Henderson, J. M. Cohen, and G. N. McDermott

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Since World War I, zirconium has been used in industry largely for the production of nonmetallic materials. However, its use is rapidly expanding, owing to the Atomic Energy Commission's interest in this metal, which arises from the fact that its combination of properties makes it a valuable structural material for nuclear reactors. Zirconium has good strength at high temperature, is corrosion resistant to high velocity coolants, does not form high activity isotopes, and has resistance to mechanical damage from neutron radiation.

All zirconium ore contains small amounts of hafnium. Hafnium has a high thermal neutron capture while pure or reactor-grade zirconium (hafnium-free) has a low neutron capture; hence, for most nuclear applications, reactor-grade zirconium is required. Because of marked similarity in their respective chemical and physical properties, hafnium can be separated from zirconium only by special techniques.

Within the past decade, almost the entire production of reactor-grade (hafnium-free) zirconium came from one commercial firm. The following schedule indicates the steady annual increase in production of this valuable metal (1):

Year	Production (lb)
1953	160,000
1954	200,000
1955	250,000
1956	325,000

To meet the ever-increasing demand for pure zirconium, the Atomic Energy Commission has contracted for several million pounds of reactor grade zirconium to be delivered over a five-year period. In 1956 alone, the AEC contracted for a total of 1,225,000 lb. By 1965 the demand could reach 10 million pounds yearly. Several companies are now or shortly will be engaged in its production.

The manufacture of reactor-grade zirconium can be considered as a two-step process. The first step is the separation of halfnium from zirconium by chemical means. This process produces all of the liquid wastes. The second step is the reduction of the purified hafnium and zirconium compounds to pure metal. This latter step produces only uncontaminated cooling water.

Objective

Since no known prior information existed on the liquid wastes produced by this growing industry, a survey was made on the wastes discharged by one plant to determine (a) the volume, composition, and polluting effects of component and combined liquid process wastes, and (b) the effect of these wastes on the receiving stream, especially with reference to fish life (2). Emphasis was placed on the individual production sources of liquid wastes, which provide the most useful data for determining the ap-

propriateness of segregation and separate treatment. A survey of this type can provide bases for possible process modifications to eliminate or reduce certain waste loads.

Although the technology involved in the production of reactor-grade zirconium is changing rapidly, the methods and techniques discussed in this paper can generally be applied or adapted to defining the pollution problems involved. The toxicity information on ammonia, cyanides, and other waste constituents, and the bio-assay data on pure compounds can also generally apply.

Manufacturing Process

The basic raw material of the process is commercial zirconium tetrachloride, and the products are metallic zirconium and hafnium. These two purified metals are produced in the approximate ratio of 2 lb of hafnium per 100 lb of zirconium. For each pound of pure zirconium produced, the quantities of materials shown in Table I are added as make-up to the recirculating chemical solutions or are used in consumptive steps.

TABLE I.—Raw Materials for Manufacture of Hafnium-Free Zirconium

Chemical	Pounds per Pound of Zirconium Produced
Zirconium tetrachloride	2.6
Ammonia	2.2
Hydrochloric acid	2.8
Ammonium thiocyanate	0.30
Sulfuric acid	1.5
Chlorine	0.5
Methyl isobutyl ketone	0.071
Phthalic anhydride	0.51

Commercial zirconium tetrachloride is made by melting the mineral zircon with carbon in an electric furnace and burning the resulting carbonitride in a chlorine atmosphere. The commercial zirconium tetrachloride contains about two per cent hafnium, plus other metal impurities. Hafnium is separated from zirconium by taking advantage of the differences in the distribution coefficients for the compounds of these two elements in aqueous and nonaqueous solvents.

The commercial zirconium tetrachloride feed is dissolved in water, ammonium thiocyanate is added, and the acidity is adjusted with hydrochloric acid. The process is presented in Fig-

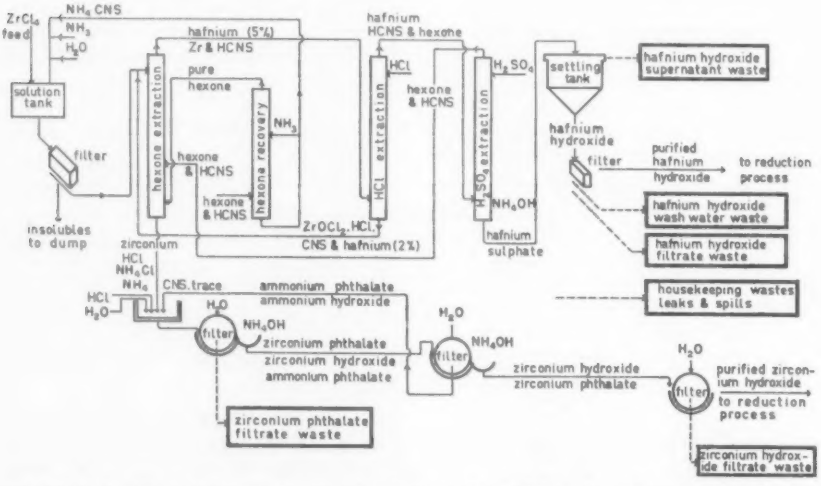

FIGURE 1.—Flow diagram of separation process for hafnium-free zirconium production.

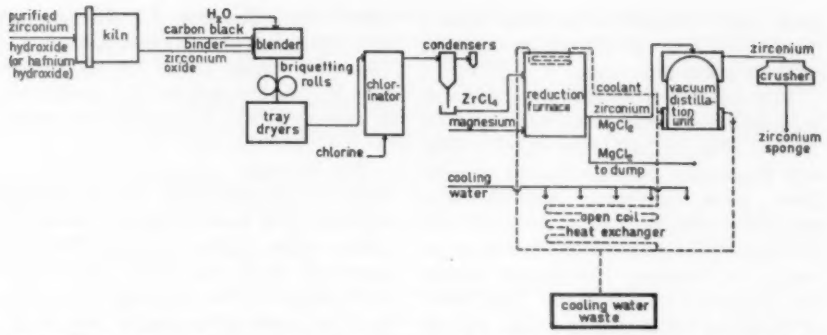

FIGURE 2.—Flow diagram of reduction process for hafnium-free zirconium production.

ures 1 and 2. The aqueous solution of hafnium and zirconium thiocyanates is repeatedly extracted in countercurrent extraction columns with methyl isobutyl ketone, a water-immiscible organic solvent referred to as hexone. The hafnium compound tends to concentrate in the hexone phase while the zirconium compound remains principally with the aqueous phase.

Waste Sources

The acidic, aqueous zirconium phase is treated with ammonium phthalate which precipitates zirconium phthalate. The soluble portion, containing ammonium chloride and hydrochloric acid plus small amounts of thiocyanates and chlorides of iron, aluminum, and other metals, is separated from the phthalate precipitate by means of filters and is discarded to sewers. This waste is designated as "zirconium phthalate filtrate" waste.

Ammonia is added to the zirconium phthalate slurry, causing the zirconium to precipitate as the hydroxide or hydrate. The suspension is filtered, and the strong ammonium phthalate solution is recycled. Three serial precipitations and filtrations are performed on the slurry. On the final filter, traces of ammonium phthalate are water-washed from the solid zirconium hydroxide on a rotary drum vacuum filter. The filtrate is washed to the sewers. This waste is designated as "zirconium hydroxide filtrate" waste.

The moist zirconium hydroxide then continues to the calcining, briquetting, and reducing operations which produce no liquid wastes.

The hexone solution from the extracting columns, containing hafnium thiocyanate, thiocyanic acid, and small amounts of zirconium thiocyanate, is treated with hydrochloric acid solution to remove substantially all of the remaining zirconium compounds. The aqueous acid zirconium extract is recycled to the hexone extraction column feed.

Following hydrochloric acid treatment, the hexone solution is extracted with a sulfuric acid solution. This forms water-soluble hafnium sulfate which is withdrawn from the bottom of the tower while the hexone phase is recycled. Ammonium hydroxide solution is added, precipitating the hafnium as the hydroxide, which is allowed to settle in a settling tank. The supernatant, containing ammonium sulfate, ammonium thiocyanate, and traces of hexone, is permitted to overflow the settling tank to sewers. This waste is designated as "hafnium hydroxide supernatant" waste. The settled sludge is drawn to plate and frame filters. The filter cake is water washed, and the filtrate is washed to the sewer. The filtrate is designated as "hafnium hydroxide filtrate" waste

and "hafnium hydroxide wash water" waste. Both are produced on an intermittent schedule.

The moist zirconium hydrate is calcined, then briquetted with organic binder plus carbon, and dried. The dry briquettes are chlorinated to produce pure zirconium tetrachloride, and the latter is reduced to metal by heating with magnesium metal in a reduction furnace. No liquid wastes are produced in this step. Reduction of hafnium hydroxide to metal follows the same general process.

Waste Handling

The wastes disposal method in the plant studied consists in principle of disposal by dilution. The wastes are discharged to two holding lagoons, designated "A" and "B". All of the strong process wastes are discharged to lagoon "A", which is of sufficient capacity to retain several weeks' flow. These stored wastes are subsequently pumped and trucked to a location where adequate dilution water is available. Housekeeping wastes, leaks, and spills are collected in lagoon "B", also capable of retaining several weeks' flow. This effluent is discharged to a small stream by regulated flow in accordance with the volume of dilution water available.

Wastes Survey

Sampling and Analytical Methods

Samples of the wastes were collected for 8 hours each day, over a 7-day period. Since the major plant operations are continuous, an 8-hr period can be considered representative of the day's operation. Equal quantities of individual samples were composited at the sampling interval chosen for each point. The sampling interval varied from 15 to 60 min. These composites were then subjected to chemical analyses and fish toxicity tests.

Chemical analytical methods were, in general, based on "Standard Methods" (3). Methods for thiocyanates (4), cyanides (5)(6), and hexone (7)(8) were taken from the literature. In addition, bio-assays were performed to determine the toxicity of the wastes to fish (9).

The bio-assay procedure consists essentially of preparing various concentrations of a waste with a selected dilution water, adding the test fish, and observing their reactions over a specific period. The test fish were fathead minnows (*Pimephales promelas*). The dilution water was obtained from the receiving stream above the plant outfall. It was highly buffered in its natural state, with a pH of 8.0, an alkalinity of 200 ppm, and a hardness of 450 ppm.

From the observed fish mortality, 24- and 48-hr TL_m (median tolerance limit) values were determined by graphical interpolation. In these tests the TL_m is the concentration of waste which produces a 50 per cent mortality of the test fish and provides a direct or comparative measure of toxicity. Such a concentration will affect aquatic life in receiving waters.

The median tolerance limits were used to estimate the dilution believed necessary to provide safety for aquatic life. A factor of 10 was applied to the 48-hr TL_m data to obtain these recommended values. It is possible that the factor could vary above or below 10, depending on individual conditions. Selection of the factor of 10, based partly on previous experience, involved the following considerations:

1. Conversion from 50- per cent kill in a nonrenewed solution in a short-time period to complete survival in a continuously renewed solution for an extended period.
2. Experimental evidence that these effluents are more toxic to other native species of fish, and knowledge that, during the egg-, fry-, or other life-cycle-stage, fish and some important

TABLE II.—Characteristics of Wastes from Hafnium-Free Zirconium Production

Waste	Ammonia as NH_3 (mg/l)	Thiocyanate as CNS^- (mg/l)	Cyanide as CN^- (mg/l)	Sulfate as $SO_4^=$ (mg/l)	Chloride as Cl^- (mg/l)	Alkalinity as $CaCO_3$ (mg/l)		Acidity as $CaCO_3$ (mg/l)		pH	Hexone as $C_6H_{12}O$ (mg/l)	Sp. Gravity
						Methyl Orange	Phenolphthalein	Methyl Orange	Phenolphthalein			
Zirconium phthalate filtrate	17,700	158	1.7	49	38,400	—	—	1,960	7,290	1.6	303	1.019
Zirconium hydroxide filtrate	9,420	14	0.045	228	2,300	17,020	9,870	—	—	9.6	56	1.008
Hafnium hydroxide supernatant	69,200	6,230	10.0	151,000	3,550	58,800	39,200	—	—	9.6	1,770	1.098
Hafnium hydroxide filtrate	68,300	5,920	6.2	149,000	3,490	64,700	45,200	—	—	9.8	4,765	1.098
Hafnium hydroxide water wash	28,900	2,450	3.4	58,900	1,520	22,200	13,700	—	—	9.4	3,620	1.041
Housekeeping wastes, leaks, and spills	2,070	1,160	0.30	1,750	2,510	—	—	134	650	2.9	691	1.003

fish-food organisms are more sensitive to toxic chemicals.

3. Spills, leaks, or accidental occurrences which may temporarily increase waste concentrations.

Volume and Characteristics of Wastes

Analytical data on these process wastes, showing concentration of the more significant substances, are shown in Table II. Quantities of wastes and of components based on each 1,000 lb of zirconium produced are given in Table III. Fish toxicity data are reported in Table IV.

Pollutional Effects

The major consideration of the wastes is their potential toxicity to aquatic life. The effects of the various constituents are discussed below.

Ammonia and Ammonium Salts

Analytical data show that the single most significant component in the waste streams is ammonia. The toxicity of ammonia and ammonium salts to aquatic life is directly related to the amount of undissociated ammonium hydroxide in the solution, which, in turn, is a function of pH. A high

TABLE III.—Quantity of Wastes and Pollutional Materials per 1,000 Pounds of Zirconium Produced at One Plant

Waste	Volume (gal)	Ammonia as NH_3 (lb)	Thiocyanate as CNS^- (lb)	Cyanide (CN^-) (lb)	Sulfate ($SO_4^=$) (lb)	Chloride (Cl^-) (lb)	Alkalinity as $CaCO_3$ (lb)		Acidity as $CaCO_3$ (lb)		Hexone as $C_6H_{12}O$ (lb)
							Methyl Orange	Phenolphthalein	Methyl Orange	Phenolphthalein	
Zirconium phthalate filtrate	11,200	1,650	14.7	0.158	4.6	3,580	—	—	182	680	28.3
Zirconium hydroxide filtrate	1,780	130	0.2	0.0068	3.4	34	253	147	—	—	0.83
Hafnium hydroxide supernatant	950	540	49.2	0.078	1,190	28	464	310	—	—	13.9
Hafnium hydroxide filtrate	150	85	7.3	0.0077	185	4.3	80	56	—	—	5.9
Hafnium hydroxide water wash	82	20	1.7	0.023	41	1	15	9	—	—	2.5
Housekeeping wastes, leaks, and spills	12,600	220	120	0.031	184	264	—	—	14	68	72
Cooling water	990,000	—	—	—	—	—	—	—	—	—	—
Total plant wastes	26,800*	2,640	193	0.304	1,610	3,910	—	—	—	—	123

* Excluding cooling water.

TABLE IV.—Bio-assay Data from Wastes Survey of One Zirconium Producing Plant

Waste	Toxicity—48-hr TL_m* (per cent concentration of waste)	Recommended Dilution Water per Pound of Zirconium Produced (gal)
1. Zirconium phthalate filtrate	0.28	40,300
2. Zirconium hydroxide filtrate	0.16	11,100
3. Hafnium hydroxide supernatant	0.025	37,900
4. Hafnium hydroxide filtrate	0.025	5,950
5. Hafnium hydroxide water wash	0.065	1,240
6. Housekeeping wastes, leaks, and spills	2.4	5,000
7. Combined process wastes†	0.27	52,500
8. Total plant waste‡	—	57,500

* Characteristics of dilution water used in test: pH—8.0, methyl orange alkalinity as $CaCO_3$—210 ppm; hardness as $CaCO_3$—460 ppm.

† Combined process wastes (housekeeping wastes, leaks, and spills not included) after mixing and storage in a lagoon.

‡ Sum of items 6 and 7.

concentration of ammonium ions in water at a low pH may not be toxic, but raising the pH increases the toxicity (10). The combined reversible equations are as follows:

$$NH_3 + H_2O \rightleftarrows NH_4OH \rightleftarrows NH_4^- + OH^-.$$

At a pH of 6, the ratio of ammonium ions to ammonium hydroxide molecules is 1,800 to 1; at a pH of 7, it is 180 to 1; and at a pH of 8, it is 18 to 1 (11). It is evident that most of the ammonia in water at or below neutral pH exists in the form of the less toxic ammonium ions.

Ellis (12) found that the toxicity of a given concentration of ammonium compounds toward fish increased 200 per cent or more between pH limits of 7.4 and 8.0. High concentrations of ammonium ions in water may not be demonstrably toxic but should be regarded as a potential hazard to fish life if the pH is subject to considerable fluctuation. Ammonia that exceeds 2 to 2.5 ppm in the pH range of most natural waters may be expected to have some adverse effect on aquatic life.

Cyanides

The quantity of cyanides is too low to be significant when diluted with cooling water wastes and further diluted in the stream. The maximum concentration found was 10.0 mg/l in the hafnium hydroxide supernatant, which amounts to only 0.078 lb of cyanide for 1,000 lb of zirconium produced. It is possible that these traces of cyanide are the inadvertent products of reaction with thiocyanate in the plant.

A single value of 0.004 mg/l of cyanides was found in the receiving stream below the plant. This value is well below the concentration accepted as detrimental to aquatic life. Concentrations as low as 0.07 mg/l have been reported to affect aquatic life adversely (13).

Thiocyanates

The concentrations of thiocyanates in some of the waste streams were high, the "B" lagoon effluent (housekeeping wastes, etc.) to the stream averaging 1,160 mg/l. However, the concentration in the receiving stream just below the plant was found to be 8.3 mg/l. The toxicity of thiocyanates is comparatively low. Levels of 10 to 15 mg/l of sodium thiocyanate have been reported as toxic to *Daphnia magna*, a small crustacean in Lake Erie water (14). Although the normal toxic range for fish is 100 to 200 mg/l, thiocyanates may become toxic in concentrations as low as 6 mg/l when chlorinated to low residuals, owing to the formation of cyanogen chloride.

Sulfates and Chlorides

The concentrations of sulfates and chlorides discharged are high but are not considered significantly toxic to stream life after dilution in the receiving stream, though they may be significant to other water uses.

Hexone

Bio-assays on the toxicity of the solvent showed it to be unimportant at the concentrations found in the wastes.

Chlorine

Gases vented from the chlorinator may contain some free chlorine. These can be scrubbed to reduce atmospheric pollution, resulting in liquid wastes containing residual chlorine being released to streams. Chlorine residuals as low as 0.2 ppm in a stream may affect aquatic life adversely.

Toxicity of Pure Compounds

Zirconium Compounds

The toxicities of zirconium compounds were investigated by standard bio-assay procedures for acute toxicity and are reported in Table V.

Characteristics of the soft and hard waters prior to adding the test chemicals were as follows (methyl orange alkalinity and hardness reported as $CaCO_3$):

Water	pH	Alkalinity (mg/l)	Hardness (mg/l)
Soft	7.4	18	20
Hard	8.2	360	400

The zirconium compounds used in the test, being acid salts, lowered the pH of the test dilutions to the acid side. The low pH values may have contributed somewhat to the toxicity of the test solutions, but the acidity was not considered a major effect in itself. However, its effect in keeping the zirconium in solution may be important.

TABLE V.—Results of Acute Toxicity Bio-assays of Zirconium Compounds

Compound Tested	Fish Species Used	48-hr TL_m* (mg/l as Zirconium)	
		In Soft Water	In Hard Water
$Zr(SO_4)_2 \cdot 4H_2O$	Fathead minnows	14.4	144
$ZrOCl_2 \cdot 6H_2O$	Fathead minnows	17.8	239
$ZrOCl_2 \cdot 6H_2O$	Bluegill sunfish	15.3	268

* Based on amount of zirconium added.

The median tolerance limits reported for the zirconium compounds are based on the quantities of zirconium added, and do not necessarily correspond to the amount of zirconium in solution. Although several zirconium compounds, including those used in the tests, are soluble in water, others are not. Reactions of the compounds with materials present in the dilution waters, particularly in hard water, result in precipitation of the insoluble compounds. This precipitation was evidenced by the formation of flocculent materials and the effect is presumed to account for much of the wide variation in the toxicities in soft and hard water. The concentration of zirconium actually remaining in solution was not measured.

The fact that toxicity exhibited by the effluents can be accounted for by toxicity of the ammonium compounds present indicates that zirconium itself does not play a prominent role in the toxicity of these wastes.

Other Compounds

Bio-assays conducted on other pure chemicals which may be present in zirconium plant wastes, using fathead minnows as the test fish and a moderately hard water for dilution, gave the following results:

Chemical Tested	Reported as	48-hr TL_m (mg/l)
Ammonium hydroxide	NH_3	8.5
Sodium cyanide	CN	0.24
Sodium thiocyanate	CNS	107
Hexone	Hexone	750

Waste Control

As previously stated, the disposal method used by this industrial plant is dilution, with the wastes discharged to holding ponds or lagoons and thence to the receiving streams.

Lagooning of the wastes appears highly advisable because the intermittent nature of the discharge makes necessary some means of evening waste loads before eventual discharge to a stream or to further treatment. Interaction of the alkaline and acidic wastes permits neutralization, which tends to counteract short-time discharges of extremely alkaline or acidic slugs. Lagoons can be equipped with controlled outlets to adjust the discharge to the quantity of flow in the receiving stream. Loss of volatile materials and biological decomposition may result in some reduction of waste loads. Settleable materials are also removed in the lagoons.

The possibility of recovering ammonia from the wastes has been considered. As practiced in the by-product coking industry, ammonia recovery from wastes of similar ammonia content is accomplished by treatment with lime and by steam stripping. Lime treatment is necessary to convert the ammonium salts, such as sulfates and chlorides, to ammonium hydroxide, which is more readily steam stripped from the solution. With lime treatment, a high content of sulfates in the combined process wastes results in the production of calcium sulfate sludge, which requires disposition. The economics of an ammonia-recovery operation would depend, among other things, on the volume of wastes to be stripped. As an estimate, it would appear advantageous to strip the process wastes only, and not include the housekeeping wastes, leaks, and spills. At 95-per cent efficiency in recovery of ammonia from the process wastes, the residual ammonia load in the plant wastes is estimated to be 0.32 lb per pound of zirconium produced.

The waste load from housekeeping wastes, leaks, and spills could be reduced by (a) improved control of operating procedures and better equipment or maintenance to minimize leaks and spills; (b) provision for the return of all strong chemical solution leaks and equipment drainings, such as tank and line residues, to the process; (c) provision for the recovery of chemicals; or (d) treatment of the wastes.

Consideration has also been given to chlorination of the wastes for destruction of the ammonia and cyanide. To oxidize the ammonia by chlorination, it would also be necessary to oxidize the thiocyanates and cyanides and possibly all organics present. A partial chlorination might conceivably increase the toxicity of the wastes. Use of the waste chlorine gases vented from the chlorinator in the zirconium oxide reduction operation can be considered as a partial source of the chlorine required for chlorination.

Dilution Factors

The dilution water quantities recommended for the individual process wastes in Table IV indicate that 102,000 gal of dilution water per pound of zirconium produced are needed for disposal of the total wastes. Toxicity of the combined process wastes (not including housekeeping wastes, leaks, and spills) was considerably less than the total toxicity of the individual effluents. The dilution quantity recommended for the combined process wastes was 52,500 gal per pound of zirconium produced.

This reduction was probably due to the varying chemical characteristics of some of the individual wastes. The waste containing the highest concentration of ammonia, the hafnium hydroxide supernatant, also had a high pH value and would reflect the maximum toxicity of ammonia. When mixed with acidic wastes and with

consequent lowered pH, a lower toxicity would be indicated. The total toxicity also may have been reduced by loss of volatiles, oxidation, or other chemical reaction in the lagoon.

Although the above TL_m values apply to this dilution water, they can be used to estimate the toxicity in other receiving waters. The nature of the constituent (ammonia) primarily responsible for the toxicity of these wastes is such that toxicity increases in receiving waters with higher pH values.

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SPRING IS THE TIME TO PLAN

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OCTOBER 12–15

(See p. 541)

SECONDARY PETROCHEMICAL PROCESSES AS WASTE SOURCES *

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This is the second of several papers from an Industrial Wastes Symposium, titled "The Petrochemical Industry." The first paper was "Basic Petrochemical Processes as Waste Sources," This Journal, **31**, 3, 274 (Mar. 1959). Other papers in this series will appear in early issues of This Journal.

Any review of waste disposal problems associated with the petrochemical industry must recognize the scope of chemical operations involved. From petroleum based hydrocarbons through one or two steps of chemical transformation, there emerge some 200 industrial products. If further processing steps are considered the number reaches the thousands. Each of these products has its own set of properties, its own toxicity, and poses its own resultant waste disposal problems.

Common Characteristics

In looking at this great profusion of products and processes through the eyes of a waste disposal engineer, there are noted wastes arising out of certain characteristics common to all chemical processing operations. These are:

1. By-product formation.
2. Side reactions.
3. Incomplete reactions.
4. Mechanical loss problems.

A by-product can be defined as a material resulting from inevitable stoichiometry of the process. For example, hydrochloric acid is a by-product of most chlorination reactions, hydrogen is a by-product of dehydrogenation processes, and so on. These by-products may be saleable commodities like hydrochloric acid, or useless nuisances like the dilute brine solutions from certain caustic hydrolysis reactions. Unfortunately the laws of stoichiometry and the laws of the market place are not related. Thus, today's profitable by-product sometimes becomes tomorrow's waste disposal headache.

The presence of side reactions gives rise to various unwanted products varying from isomers of the main product to unrecognizable gunks and tars. In contrast to stoichiometric by-products, these side products are subject to some degree of control, both with respect to quantity and identity. One of the classical tasks of chemical research has been to reduce the amount of side products or to upgrade them into products of some usefulness. Even so, many of these materials still go out the stacks, down the sewers, or out to the waste dumps.

In the domain of chemistry in practice, as opposed to chemistry in theory, no raw material is completely pure, nor is any reaction 100-per cent complete. In today's competitive economy, customers are seldom willing to buy the impurities in raw materials in the form of impurities in the final product. Thus for the production of

* Presented at the 31st Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; Detroit, Mich.; Oct. 6–9, 1958.

each saleable product there results the generation of one or more non-saleable process streams. In some cases these streams are high in unreacted raw materials which can be recycled within the process. In other cases, these streams have no recoverable economic value. If raw materials are cheap and waste disposal simple, recycling may not be economically justified. On the other hand, if both raw materials and waste disposal are expensive, then every effort must be made to recover the maximum yield of product.

Finally, there are the mechanical problems that plague every material handling operation. Some of these are emergency in nature: leaks, spills, explosions, and other unforeseen disasters of a minor or major magnitude. Other events are the result of human error: the operator who opens or closes the wrong valve; the repairman who dumps his oil or solvents into the sewer; or the engineer who fails to foresee the effect of a process change on his waste production. Regardless of origin, these mechanical losses can be held to a minimum only by good engineering design and well-trained, alert people stimulated by a plant management intent on reducing pollution to a minimum.

In addition to the foregoing generalities this paper will consider some of the more important petrochemical processes with their resultant products and characteristic problems.

Oxidation

In terms of tonnage of product, the largest chemical use for methane is in oxidation to form synthesis gas, carbon monoxide and hydrogen, which serves as the raw material for methanol or ammonia production. At present, about two million tons of methane per year are being used in this way (1).

Other processes use oxidation somewhat more directly. For example, the oxidation of propane and butane to form various aldehydes, alcohols, and acids is one of the older petrochemical oxidation processes, as is the oxidation of ethylene to yield ethylene oxide. Newer processes are those that yield phenol and acetone from cumene through oxidation and cleavage; and glycerine from the acrolein process, which involves a series of steps starting with oxidation of propylene to acrolein and ending with oxidation of allyl alcohol to glycerine by hydrogen peroxide.

Oxidation processes generally are characterized by rather low conversions and high yields of side products. For example, in the oxidation of propane-butane, about 70 per cent of the feed is converted to acetaldehyde and other useful products (2). In the propylene-acrolein-glycerine process the over-all yield is said to amount to 50 to 60 per cent based on propylene (3).

Hydration of olefinic hydrocarbons is akin to oxidation in the sense that oxidized products, alcohols or aldehydes, are produced. Hydration of ethylene to ethyl alcohol, for example, represents the second largest use for ethylene. Some 900 million lb of ethyl alcohol were produced in this way in the year 1957 (4). Other alcohols are produced by hydration of the corresponding olefins. Hydration of ace-

TABLE I.—Summary of Products from Oxidation Processes

Raw Material	Reactant	Product(s)
Methane	Steam	Synthesis gas ($CO + H_2$)
Propane, butane	Air	Acetaldehyde, etc.
o-Xylene	Air	Phthallic anhydride
Benzene	Air	Maleic anhydride
Ethylene	Air	Ethylene oxide
Cumene	Air	Phenol, acetone
Propylene	Oxygen	Acrolein
Allyl alcohol	H_2O_2	Glycerine
Ethylene	Water	Ethanol
Ethylene	Water	Ethyl ether
Propylene	Water	Isopropanol
Acetylene	Water	Acetaldehyde

tylene produces acetaldehyde. Table I summarizes these more important oxidation products.

From a waste disposal standpoint, the outstanding characteristics of these products are their water solubility and ease of biological oxidation. Plants producing these products are prone to generate dilute aqueous solutions that, although non-toxic, will quickly rob a receiving body of water of dissolved oxygen. Great vigilance, therefore, must be exercised to prevent leaks and spills. Process waste streams containing appreciable oxidizable matter must be isolated and routed to a properly designed treatment plant. Treatment consists of oxidation by standard techniques used for domestic wastewater, such as trickling filters, activated sludge, or oxidation ponds. The anticipated end result is complete oxidation of the waste to carbon dioxide and water.

Chlorination

Chemical reactions to form chlorinated products are possible by virtue of the property of the chlorine atom which allows its substitution for hydrogen in the chemical molecule. Because of the general nature of this substitution, the number of possible chlorinated products is very large. There are at least 25 such products made and sold in tonnage quantities by the petrochemical industry.

Two general types of processes are recognized: (a) direct substitution of chlorine for hydrogen, and (b) addition to an olefin. The addition may be made with chlorine, hydrochloric acid, or hypochlorous acid. It is readily apparent that the same product may be made in a number of different ways. Vinyl chloride, for example, can be produced (a) from ethylene dichloride by dehydrohalogenation, (b) from acetylene by hydrohalogenation, or (c) from ethylene by substitution chlorination.

Products formed by substitution chlorination are listed in Table II as well as the more important products resulting from dehydrohalogenation. From the waste disposal standpoint, these processes have the following important characteristics: (a) in the case of substitution reactions, hydrochloric acid is a valuable by-product; (b) the products have very limited water solubility and intermediate toxicity; (c) side reactions always occur, particularly to form isomers or higher chlorinated products; (d) when used, aqueous dehydrohalogenation necessitates the disposal of a dilute salt solution.

Table III lists some of the more important products formed by halogenation through addition to an olefin. In this case the bromine compounds also are of commercial importance. The following waste disposal characteristics are found: (a) absence of by-products; (b) generally rapid, complete reactions with low side products

TABLE II.—Products Formed by Substitution Chlorination

Reaction	Products
$RH+Cl_2 \rightarrow RCl+HCl$	Methyl chloride (CH_3Cl) Methylene chloride (CH_2Cl_2) Chloroform ($CHCl_3$) Carbon tetrachloride (CCl_4) Ethyl chloride (CH_3CH_2Cl) Ethylidene chloride (CH_3CHCl_2) Ethylene chloride (CH_2ClCH_2Cl) 1,1,2 Trichloroethane ($CH_2ClCHCl_2$) Methyl chloroform (CH_3CCl_3) Propylene chloride ($CH_3CHClCH_2Cl$) Allyl chloride ($CH_2=CHCH_2Cl$) 1,Chloropropene-1 ($CHCl=CHCH_3$) 1,3 Dichloropropene ($CHCl=CHCH_2Cl$) Perchlorethylene ($CCl_2=CCl_2$) Trichlorethylene ($CHCl=CCl_2$) Vinyl chloride ($CH_2=CHCl$) Vinylidene chloride ($CH_2=CCl_2$)

TABLE III.—Products from Halogenation Through Addition to an Olefin

Reactions	Products
$R\equiv R+X_2 \rightarrow RX=RX$	Acetylene tetrabromide ($CHBr_2CHBr_2$)
$R\equiv R+2X_2 \rightarrow RX_2RX_2$	Ethylene dibromide (CH_2BrCH_2Br)
$R=R+X_2 \rightarrow RXRX$	Acetylene tetrachloride ($CHCl_2CHCl_2$) Ethylene dichloride (CH_2ClCH_2Cl) 1,4 Dichlorobutene-2 ($CH_2ClCH=CHCH_2Cl$) Benzene hexachloride ($C_6H_6Cl_6$) Trichloroethylene ($CHCl=CCl_2$) Dichloroethylene ($CHCl=CHCl$)

TABLE IV.—Products of Hypochlorination

Reactions	Products
$R{=}CH_2 + HOCl \longrightarrow R{-}CH_2(OH)(Cl)$	Ethylene oxide $(CH_2{-}CH_2O)$
$\xrightarrow{-HCl} R{-}CH_2O \xrightarrow{+H_2O} R{-}CH_2(OH)(OH)$	Propylene oxide $(CH_3CH{-}CH_2O)$
	Epichlorohydrin $(CH_2{-}CH{-}CH_2ClO)$
	Styrene oxide $(C_6H_5CHCH_2O)$
	Glycerine ($CH_2OHCHOHCH_2OH$)
	Ethylene glycol (CH_2OHCH_2OH)
	Propylene glycol ($CH_2CHOHCH_2OH$)

(benzene hexachloride an exception because of isomer formation); and (e) products of low water solubility and intermediate toxicity.

Hypochlorination (Table IV) is used generally as a process for producing epoxides or glycol-type materials, since the primary product, a chlorohydrin, is easily dehydrohalogenated to the oxide. The largest tonnage product is ethylene oxide. About half the 1.18 billion lb of ethylene oxide produced in the year 1957 was made by hypochlorination, the remainder by direct oxidation of ethylene (4).

Hypochlorination reactions are characterized by good yields of the primary products with relatively low formation of side products. Hydrolysis of the chlorohydrins with lime produces a dilute calcium chloride solution that must be disposed of. Toxicity of the chlorohydrins is generally high, but the hydrolyzed products are of low toxicity. As in the case of oxidation processes, these products are water soluble and easily subject to biological oxidation.

Hydrochlorination (Table V) is useful for production of only two major products, vinyl chloride and ethyl chloride. The extent to which these processes are used depends on the market for by-product hydrogen chloride. In other words, a producer of chlorinated products can use these hydrochlorination processes as a means of utilizing excess by-product hydrochloric acid.

Other Processes

In addition to oxidation and halogenation, there are a number of other important processes used in the petrochemical industry. These will be mentioned only briefly. The first is polymerization of olefin hydrocarbons. Products formed may be liquid, waxy, or solid hydrocarbons. The best known example is the familiar plastic, polyethylene.

Alkylation of benzene is used to produce the important intermediates ethyl benzene, cumene, and dodecylbenzene which become styrene, phenol, and dodecylbenzene sulfonate, respectively. Alkylation of paraffins is also an important process in gasoline production.

Hydrogenation is a step in the oxo process for production of alcohols. In

TABLE V.—Products of Hydrochlorination

Reactions	Products
$R{=}R + HCl \rightarrow RHRCl$	Ethyl chloride (CH_3CH_2Cl)
$R{\equiv}R + HCl \rightarrow RH{=}RCl$	Vinyl chloride ($CH_2{=}CHCl$)

this process carbon monoxide is reacted with an olefin to produce an aldehyde which is then reduced to the alcohol by hydrogenation.

Nitration of paraffins produces a series of nitroparaffins which are useful as solvents and chemical intermediates. The process is a direct reaction between propane or other paraffin hydrocarbon and nitric acid.

Hydrocyanation produces acrylonitrile by reaction between acetylene and hydrogen cyanide. Acrylonitrile is an important monomer used as a raw material for acrylic fibers. Hydrogen cyanide is also a raw material for making organic acids, for example, adipic acid or ethylenediamine tetra acetic acid.

Processes utilizing hydrogen cyanide are unique because of the extreme toxicity to fish of HCN and some organic cyanides. HCN and lactonitrile are reported to be toxic to fish in concentrations of 0.1 ppm or less (5). Proper design must be engineered into any process to assure removal of such materials before discharge to a receiving body of water. Hydrogen cyanide can be effectively destroyed by chlorination (6).

Details of One Process

To understand the range of wastes produced from any given operation, a typical petrochemical process is considered in somewhat greater detail. For this purpose the high temperature chlorination process which produces perchloroethylene and carbon tetrachloride is discussed. Details of this process have been published (7).

Raw materials are chlorine and hydrocarbons or partially chlorinated hydrocarbons from methane through propane. Starting with ethane the chemical reactions can be written as

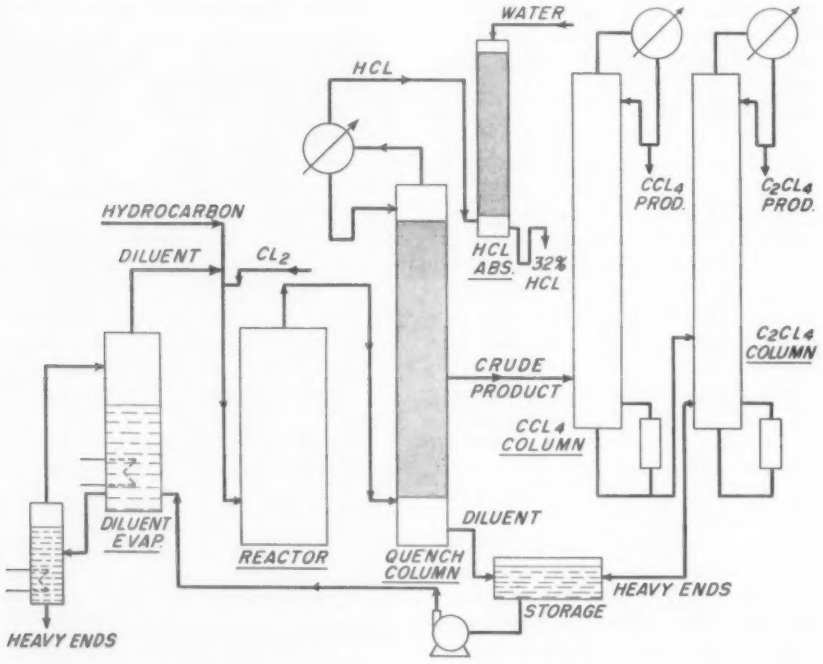

FIGURE 1.—Flowsheet of perchloroethylene process.

follows:

$$C_2H_6 + 5Cl_2 \rightarrow C_2Cl_4 + 6HCl \quad (1)$$

and

$$C_2H_6 + 7Cl_2 \rightarrow 2CCl_4 + 6HCl \quad (2)$$

At the temperature of chlorination (500 to 650°C), all the hydrogen is converted to hydrochloric acid. The hydrocarbon skeleton is cracked or reassembled to form a mixture of perchloroethylene and carbon tetrachloride.

A flowsheet of this process is shown in Figure 1. Incoming feed stock is first diluted with recycled chlorinated hydrocarbons, then mixed with chlorine and fed to the reactor. Exothermic heat of reaction maintains temperature in the reactor with addition of more diluent gas if necessary to lower the temperature.

Exit gas from the reactor contains chlorinated hydrocarbons, hydrogen chloride, some unreacted chlorine, and inerts such as nitrogen or carbon dioxide. This mixture is first fed to a quench tower where sufficient cooling takes place to condense out the bulk of the chlorinated hydrocarbons. Crude product from the quench tower is forwarded to fractionating columns where the finished products, carbon tetrachloride and perchloroethylene, are removed.

Overhead from the quench tower consists mostly of HCl, with smaller amounts of chlorinated hydrocarbons, chlorine, and inerts. This mixture is first cooled through a heat exchanger to knock out chlorinated hydrocarbons, which are returned to the quench tower, then the resulting gas is absorbed in water to remove HCl. The 32-per cent hydrochloric acid produced at this point is a saleable product. The overhead from the HCl absorber is a small gas stream consisting mostly of chlorine and inerts. This stream may be recycled to the reactor or may be discarded after a caustic wash to remove chlorine.

Heavy ends from all towers are collected and forwarded to the diluent evaporator where the light portion is returned to the process as diluent. The heavy end from the diluent evaporator represents the chief source of waste from this process. These heavy ends consist of hexachlorobenzene, hexachlorobutadiene, and hexachloroethane. This pasty mixture is generally disposed of by burial. From 2 to 10 per cent of the yield of the process is in the form of these heavy ends.

To summarize, the following waste products are produced from the high temperature chlorination process which produces perchloroethylene and carbon tetrachloride:

1. Heavy chlorinated hydrocarbons.
2. Caustic scrub liquors on bleed from the chlorine recycle system.
3. Inert gases from the caustic scrubber.
4. Cooling water from heat exchangers.
5. Chlorinated hydrocarbons or hydrochloric acid from accidental leaks or spills.

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Stream Pollution

RESPONSE OF FISH TO SUB-LETHAL EXPOSURES OF ORGANIC PHOSPHORUS INSECTICIDES *

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Introduction of toxic substances into the aquatic environment is not only a problem concerned with the immediate effect on the organisms living in this environment, but of the potential hazard to those who might possibly consume the contaminated water. Although the probable concentrations of these substances would be very low, the potential hazard does exist. In addition there are the unknown effects resulting from chronic exposure.

The ever increasing use of highly-potent insecticides for the control of agricultural pests has raised the significant question of the effect of these compounds on other animal forms found in association with the insects (1). The associated forms will be not only on the land and in the air but also in the aquatic environment. The hazard to the aquatic environment lies in the occasional indiscriminate dumping of unused insecticide in convenient bodies of water, careless application or runoff from sprayed areas reaching streams or ponds, or direct application to bodies of water to control aquatic larval stages.

The toxicity of the organic phosphorus insecticides to fish life is very high. Although generally not as toxic as the chlorinated hydrocarbons, some have a 96-hr median tolerance limit as low as 0.2 mg/l (2). Chemical analysis for very low concentrations of organic phosphorus insecticides usually involves identification of some specific fraction of the larger molecule, the bio-assay of residues from plants or plant products, or the inhibition of the enzyme cholinesterase *in vitro* (3). No specific test has been developed which permits demonstration of the presence of organic phosphorus insecticides in water at concentrations of 0.1 mg/l or less. No tests have been described which can establish that the water has a history of past contamination.

This paper describes studies concerned with demonstrating the presence of low concentrations of organic phosphorus insecticides, either concurrent with the presence of the compounds or indicating that the compounds had been in the water at some time prior to the time of the assay. The method utilizes the *in vivo* inactivation of fish-brain acetylcholinesterase (AChE).

In summary of the function of AChE in insects and vertebrates, Metcalf (4) notes its extreme importance in nerve transmission as shown by: (a) its universal presence in nerve and muscle tissue; (b) its localization at neuronal surfaces; (c) the rapid rate at which it hydrolyzes acetylcholine; (d) the fact that normal synaptic functioning depends on its presence; and (e) that the absence of AChE in the central nervous system causes death. The organic phosphorus insecticides have been

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shown to be unusually active inhibitors of cholinesterase both *in vivo* and *in vitro*.

Utilizing anti-AChE compounds analogous to organic phosphorus insecticides, Weiss (5) showed that small fish exposed to these materials had a reduction in brain AChE proportional to the concentration of the substance and extent of exposure. Death occurred when the brain AChE fell to from 30 to 60 per cent of normal. Following sub-lethal exposures, brain AChE returned to normal levels over a period of from two to three weeks. Sub-lethal exposure to anti-AChE compounds, with reduction in brain AChE, rendered the fish more susceptible to subsequent exposures in the early stages of recovery.

Laboratory Procedures

Brain Tissue Preparation

The determination of acetylcholinesterase activity was carried out according to the procedure described by Weiss (5). Several minor modifications were made in the described technique to minimize experimental errors. Following excision of the fish brain and wet weighing, the brain was homogenized in a phosphate buffer of the following composition: 0.2M NaCl, 0.02M $MgCl_2$, 0.194M K_2HPO_4, and 0.006M KH_2PO_4, with the final pH adjusted to 8.2. The brain brei (homogenized brain tissue) was then diluted to approximately 3.5 mg/ml with this buffer. The dilutions were made in graduated cylinders and the volume measured to the nearest 0.1 ml to approximate the desired tissue concentration of 3.5 mg/ml. In the range of tissue concentration of from 1 to 4 mg/ml, the greatest enzyme activity was found at about 3.5 mg/ml. Variation in activity between the extremes of tissue concentration, however, was less than 10 per cent.

In addition to adopting a standard tissue concentration for each assay, it was observed that following homogenization and dilution of the brain tissue, there was a consistent and steady rise in enzyme activity for about 4 hr. The change in activity was approximately 1.5 to 1.8 times the initial activity. Since it was not practical to carry out the assay immediately following homogenization, the diluted brain brei was allowed to stand at 25°C for 4 hr prior to the determination of AChE activity.

Measurement of AChE Activity

At the end of 4 hr, 1 ml of 0.004M acetylcholine was added to the 1-ml aliquot of diluted brain tissue and allowed to incubate for exactly 20 min at 25°C. The residual acetylcholine was then determined colorimetrically by reaction with alkaline hydroxylamine and ferric chloride (6). The color developed is read on a photometer. The AChE activity is reported in terms of micromoles of acetylcholine hydrolyzed per milligram of brain tissue per hour.

Exposure Tests

Exposures of fish to organic phosphorus insecticides were carried out in 5-gal wide-mouth jars. The water used was Chapel Hill tap water, dechlorinated by passage through a charcoal filter. The pH of the water was adjusted to 6.5 with an appropriate volume of 1M KH_2PO_4. In this slightly acid water, hydrolysis of the organic phosphorus compounds was minimized (7). The alkalinity and hardness of the water averaged about 40 mg/l.

The jars were calibrated to 15 l and filled to this volume for all tests. No more than 14 specimens of the four species used were placed in any jar. When large numbers of fish had to be exposed at the same concentration to allow for survivors for recovery studies, duplicate jars were prepared. All exposures were made at 20°C ± 0.1°C and the water was saturated with oxygen just prior to the start of an experiment.

Organic phosphorus insecticide samples were weighed in tared 100-ml volu-

TABLE I.—Organic Phosphorus Insecticides

Compound	Purity	Manufacturer
Parathion	Technical	American Cyanamid Co.
Diazinon	Technical	Geigy Co.
Malathion	89% technical	American Cyanamid Co.
Demeton	Technical Systox	Chemagro Corp.
EPN	45% technical	E. I. du Pont de Nemours & Co.
Chlorthion	98% technical	Bayer A. G.
Guthion	Technical	Bayer A. G.
Hercules 528	47% active	Hercules Powder Co.

metric flasks and dissolved in either ethyl alcohol or acetone. This stock solution, usually in the range of from 200 to 1,000 mg/l, was then added in the appropriate quantity to the 15-l jars to provide the desired insecticide concentration or diluted once more in the organic solvent before adding to to the water. In this manner no problem of water solubility was encountered since the final insecticide concentration when added to 15 l was considerably below the solubility limits of all compounds tested. The quantities of ethyl alcohol or acetone added to the 15 l varied between 1 and 15 ml and had no effect on the fish.

After adding and mixing the organic phosphorus insecticide, a suitable number of fish were introduced. Following various times of exposure to the particular compound being tested, pairs of fish were dipped from the tank, wrapped in aluminum foil, identified, and placed in a freezer at − 25°C until the brain assay was carried out. At this storage temperature there was no detectable change in normal fish-brain AChE activity for periods upwards of 6 months. In most instances, storage was for only one or two weeks.

In experiments designed to study recovery of AChE activity, the fish were removed from the jars following their period of exposure to the insecticide and transferred to recovery tanks. In these tanks they were handled as normal fish with constant aeration and routine feeding and changing of tank water. At suitable intervals pairs of fish were removed and stored in the freezer until the brain assays were made.

The organic phosphorus insecticides used in this study are noted in Table I.

Brain Activity of Normal Fish

In earlier studies on fish-brain cholinesterase it was realized that both variation in activity per unit weight of brain and variation between species were problems that had to be investigated extensively in order to develop a basis for systematic use of the enzyme-inhibition assay as a method of detection of organic phosphorus insecticides in water (5). With this in mind an extensive study was initiated to determine brain weight and brain enzyme activity relationships in as wide a variety of common fish species as feasible. Specimens for this investigation were obtained from hatcheries, traps, commercial seining, trawls, lake drainings, and rotenone removal of fish.

The variation of brain-enzyme activity per unit of brain weight for the four species of fish used in the experiments is shown in Figure 1. To determine the curve of best fit for the array of points representing each species, the data were programmed for an electronic computer and the equations of the curve of best fit calculated. This was done for three of the four species; the curve shown for goldfish was fitted by eye.

These curves represent for each species the acetylcholinesterase activity that can be expected from brain specimens of unexposed fish. By knowing the brain weight, a value for the expected activity can be estimated from the appropriate curve. If an expected value can be estimated, then the effect of exposure to an anti-cholinesterase compound can be measured. This is done by first determining the activity of an exposed specimen and then comparing it with the curve value. Deviations are expressed as a per cent of the normal AChE activity.

In comparing deviations, the outer-

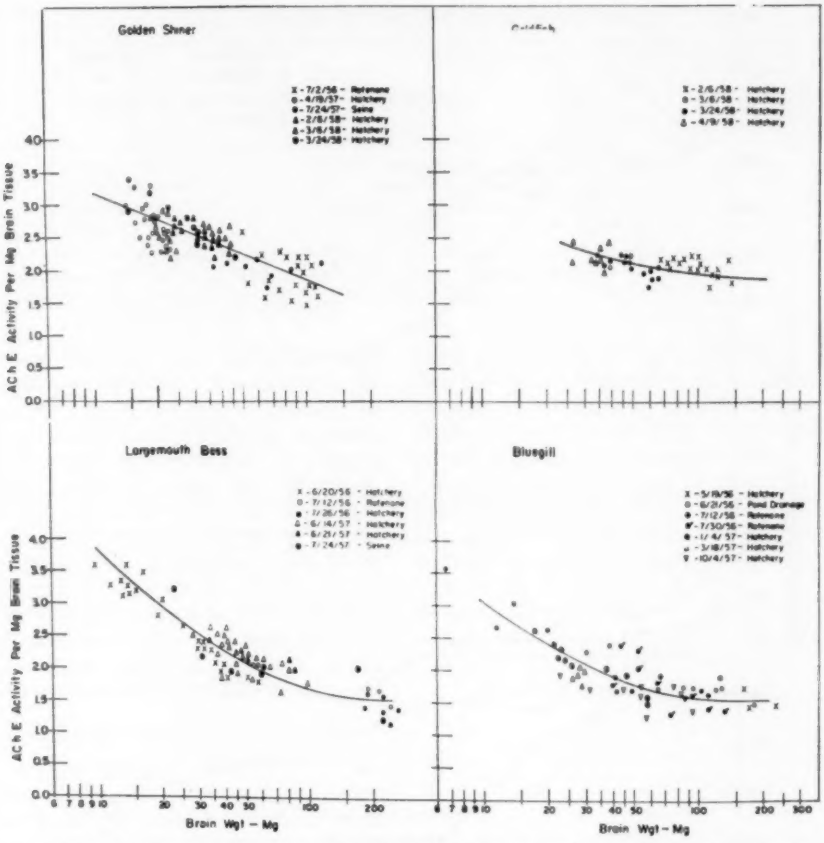

FIGURE 1.—Relationship of normal AChE activity to brain weight for four species of fish.

most values above and below the curve of best fit were selected as the limits of normal variation for unexposed specimens. These limits are shown by dotted lines on the figures illustrating experimental data. The limits of variation are about 12 to 15 per cent above and below the value determined by the curve of best fit.

Studies on normal AChE activity are continuing to provide information on other species that might be used for experimental purposes or for reference if such species should be taken from waters that might have been subjected to pollution by organic phosphorus insecticides.

Results

Reduction of Enzyme Activity

Exposure of fish (Table II) to a series of organic phosphorus insecticides at the same concentration illustrates both the relative response time and the relative effectiveness of the compounds in inhibiting the brain-enzyme activity. The results of an experiment in which goldfish were exposed to eight organic phosphorus compounds are shown in Figure 2. Seven of the compounds were at a concentration level of 0.1 mg/l and one at 0.01 mg/l. The latter, Guthion, produces about the same inhibitory effect as the

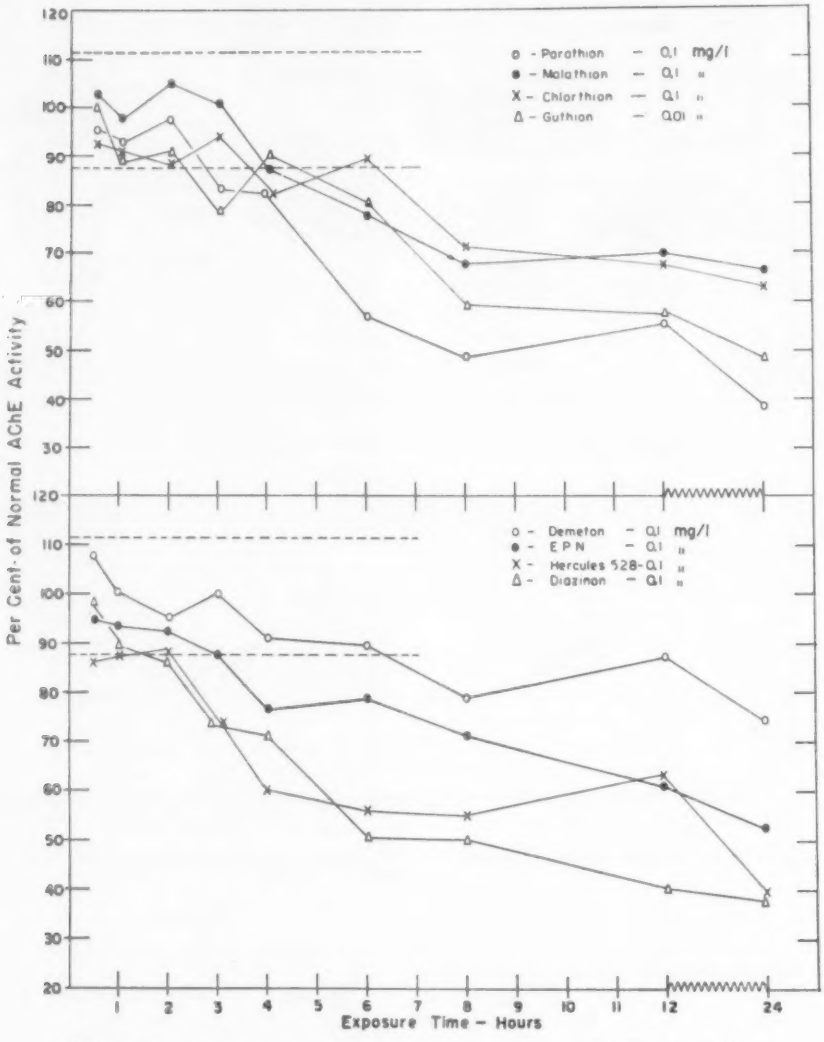
o - Parathion — 0.1 mg/l
● - Malathion — 0.1 "
X - Chlorthion — 0.1 "
Δ - Guthion — 0.01 "
o - Demeton — 0.1 mg/l
● - E P N — 0.1 "
X - Hercules 528 - 0.1 "
Δ - Diazinon — 0.1 "
Per Cent of Normal AChE Activity
Exposure Time - Hours

FIGURE 2.—Response of goldfish to eight organic phosphorus insecticides.

others but at one-tenth the concentration. The other seven compounds produce generally parallel trend lines. At the end of 24 hr, AChE activity was less than 40 per cent of normal for specimens exposed to parathion, Hercules 528, and Diazinon; just over 50 per cent for EPN; about 65 per cent for Chlorthion and malathion; and 75 per cent for Demeton. Twenty-four hour exposure to Guthion, at 0.01 mg/l, reduced AChE activity to just under 50 per cent of normal.

Response Time

Another way of analyzing the data from this experiment would be to compare the exposure times necessary to

TABLE II.—Fish Species Used in Experimental Exposures

Common Name	Scientific Name	Approximate Size Ranges	
		Length (mm)	Brain Weight (mg)
Bluegill sunfish*	*Lepomis macrochirus*	50 to 90	23 to 85
Largemouth bass*	*Micropterus salmoides*	65 to 85	35 to 50
Golden shiner†	*Notemigonus crysoleucas*	45 to 70	15 to 35
Goldfish†	*Carassius auratus*	45 to 65	43 to 75

* Obtained from Fish and Wildlife Service Hatchery, Hoffman, N. C.
† Obtained from Berry Water Gardens, Inc., Kernersville, N. C.

reduce AChE activity below the range of normal variation. For example, the exposure times required to produce detectable enzyme inhibition at an insecticide concentration of 0.1 mg/l are as follows: for Hercules 528, Diazinon, and parathion, 2 to 3 hr; for EPN, 3 to 4 hr; for malathion, 4 to 6 hr; for Demeton and Chlorthion, 6 to 8 hr. Guthion, at 0.01 mg/l, inhibited below the limit of variation in from 4 to 6 hr. This order of response is essentially the same as the order of degree of inhibition after a 24-hr exposure.

Effect of Specimen Size

In the exposure of fishes to toxic compounds, the problem of specimen size relative to dosage or response time is of paramount importance. To examine this question, specimens of largemouth bass of varying size were exposed to a Guthion concentration of 0.12 mg/l (Figure 3). Initially, the smaller fish respond faster but at the end of 2 hr the total per cent change from normal is about the same for all sizes. Within the size range examined, size is apparently not a critical factor. In each experiment reported in this study fish were generally of the same size except where sorted by size for specific purposes.

Recovery from Exposure

The various fish species respond to the various organic phosphorus insecticides, as measured by AChE activity, in characteristic fashion. In Figures 4 and 5 the results of exposure of largemouth bass and bluegills to four different organic phosphorus compounds are shown. The concentrations used were of the magnitude to simulate a sudden "slug" of insecticide and a relatively short exposure. Following exposure to the "slug," the fish were transferred to fresh water and the recovery to normal AChE activity was followed. Although exposure ceased at 1½ hr, the subsequent change in AChE activity

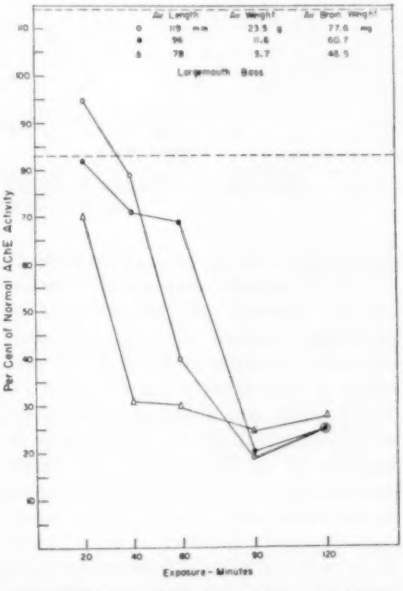

FIGURE 3.—Effect of size on the response of largemouth bass to Guthion at a concentration of 0.12 mg/l.

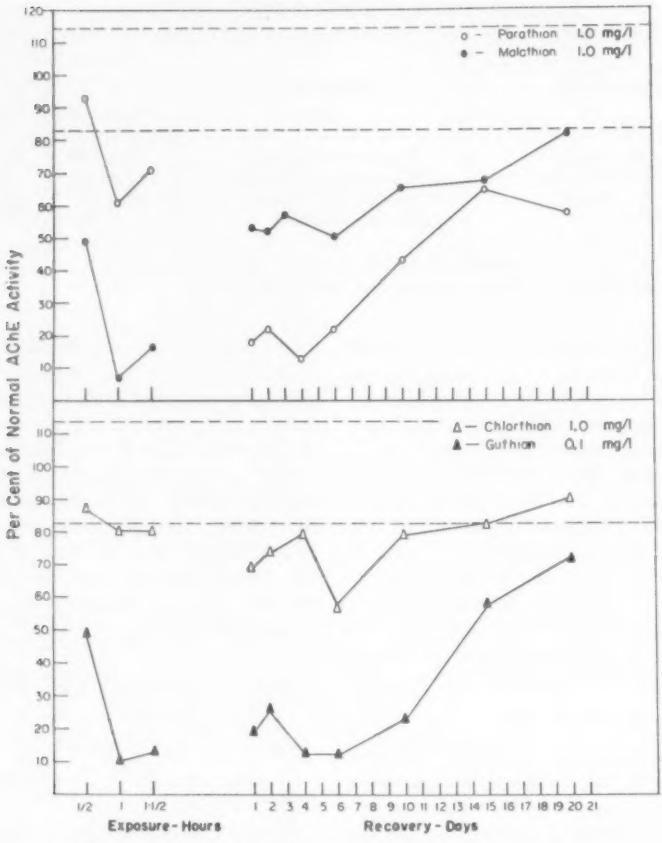
o – Parathion 1.0 mg/l
● – Malathion 1.0 mg/l
Δ – Chlorthion 1.0 mg/l
▲ – Guthion 0.1 mg/l
Per Cent of Normal AChE Activity
Exposure - Hours
Recovery - Days

FIGURE 4.—Changes in AChE activity of largemouth bass during exposure and recovery periods.

during the first 24 hr was characteristic of the specific compound. Brain-enzyme activity of fish exposed to parathion showed a continued drop even after transfer to fresh water with either a considerable lag before a recovery trend was noted or, quite often, a delayed lethal effect. The initial reduction of AChE activity of largemouth bass was greater from exposure to malathion than from parathion, but the subsequent delayed effect of parathion and more rapid recovery from malathion exposure reversed the relative positions of the two exposure and recovery curves. In comparison, the bluegills had a delayed lethal effect from parathion, and the malathion-exposed fish were in the normal range after two days' recovery. Largemouth bass recovered in 20 days from malathion exposure but AChE activity was only 60 per cent of normal 20 days after exposure to parathion.

The comparative exposure of largemouth bass and bluegills to 1.0 mg/l of Chlorthion and 0.1 mg/l of Guthion showed a species difference similar to that noted for exposure to malathion and parathion. The exposure of largemouth bass to Chlorthion resulted in only a slight drop in enzyme activity

with maximum reduction occurring after transfer to fresh water. The drop was followed by a rise to the normal range in 15 days. The bluegills, however, showed no significant deviation from the normal range after 1½ hr of exposure to Chlorthion and no subsequent lag effect. The exposures to Guthion showed for both species a very rapid and marked reduction in activity but recovery to normal range was considerably extended for the largemouth bass. Recovery was only 70 per cent of normal after 20 days for the largemouth bass while the bluegills were within the normal range after 12 days.

Using the golden shiner as a test fish, comparison of AChE activity was made with 0.1- and 0.01-mg/l solutions of Diazinon, Guthion, and EPN (Figure 6). At both concentrations, EPN demonstrated no immediate significant effect. However, a delayed reaction, apparent in the first five days of the recovery period in fish exposed to 0.1 mg/l, resulted in a reduction in AChE activity that persisted at about 70 per cent of the normal through the 22 days that the recovery was studied. Even at 0.01 mg/l the delayed reaction of EPN was apparent with the recovery curve

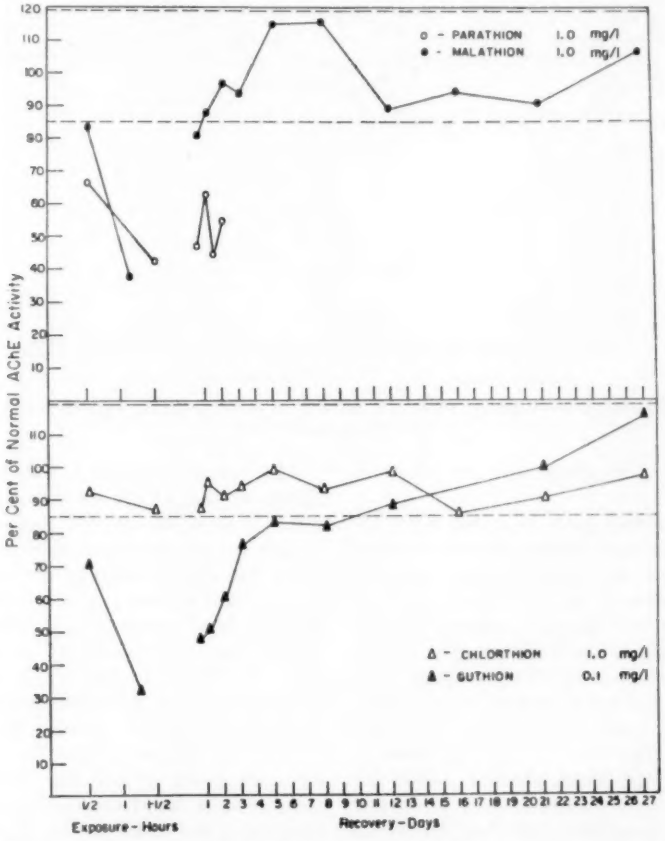
o - PARATHION 1.0 mg/l
● - MALATHION 1.0 mg/l
Δ - CHLORTHION 1.0 mg/l
▲ - GUTHION 0.1 mg/l
Per Cent of Normal AChE Activity
Exposure - Hours
Recovery - Days

FIGURE 5.—Changes in AChE activity of bluegills during exposure and recovery periods.

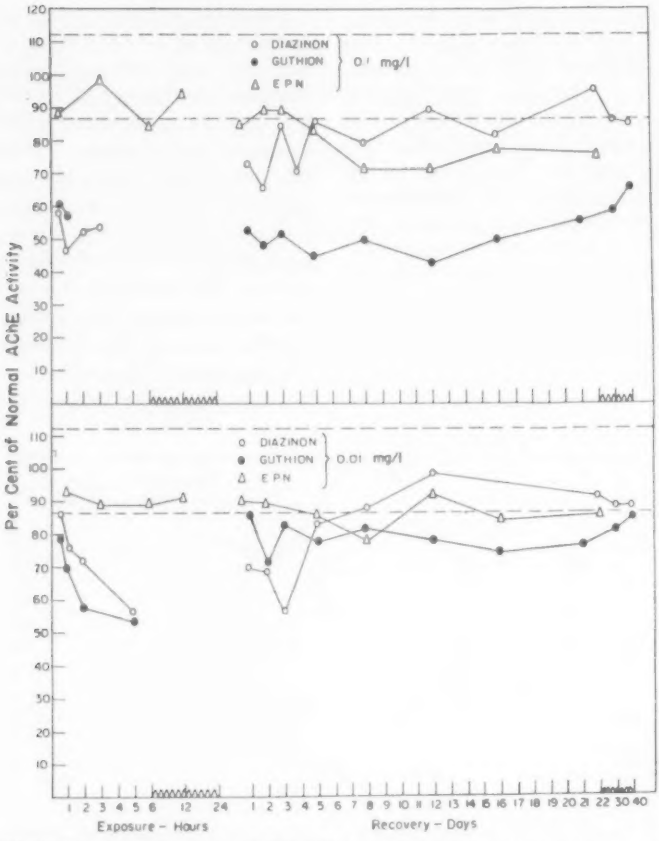

FIGURE 6.—Changes in AChE activity of shiners during exposure and recovery periods.

persisting at about 85 per cent of normal.

In contrast, both Diazinon and Guthion produced immediate and marked reductions of brain-enzyme activity. In the recovery periods after exposure to 0.1 mg/l of Diazinon, regeneration of brain AChE approached the lower limit of the normal range within three days but did not consistently stay above this limit until nearly three weeks had passed. The Guthion-exposed shiners, on the other hand, showed AChE activity which remained at 40 to 50 per cent of normal for more than two weeks and recovered to only 65 per cent of normal after 45 days.

The shiners exposed to 0.01 mg/l of Diazinon had AChE activity above the lower limit of the normal range by the eighth day of recovery and it remained there for the 40 days of the recovery period. The shiners exposed to Guthion at 0.01 mg/l, surprisingly, showed a marked rise in brain AChE in the first day of recovery but then activity dropped slightly and held constant at about 75 to 80 per cent of the lower limit of the normal range. By the 40th day, the brain AChE had finally approached the lower limit of the normal range and the trend of the curve indicated that recovery would continue into the normal range.

The peculiar delayed effect of parathion on brain AChE was further examined with particular attention given to the changes in AChE activity in the period immediately following exposure (Figure 7). Goldfish and shiners were exposed to "slugs" of 1.0 mg/l of parathion for one hour. Simultaneous comparison was made with shiners exposed to 0.3 mg/l of parathion and 0.3 mg/l of Chlorthion. The exposures at the 0.3-mg/l concentrations extended to 21 hr.

Subsequent to exposure to 1.0 mg/l of parathion for one hour, both the goldfish and shiners showed continued reduction in brain AChE activity. In the case of the goldfish, this reduction was about 40 to 50 per cent of normal and this level persisted for 10 days before a trend of recovery was well established. However, after 20 days the AChE activity in the goldfish had recovered to only 70 per cent of normal.

The brain AChE activity of the shiners exposed to 1.0 mg/l dropped from the 70-per cent value noted on removal from the exposure tanks to a low of 25 per cent on the sixth day of recovery. At that time a trend in the increase in AChE activity was established, reaching nearly 50 per cent of

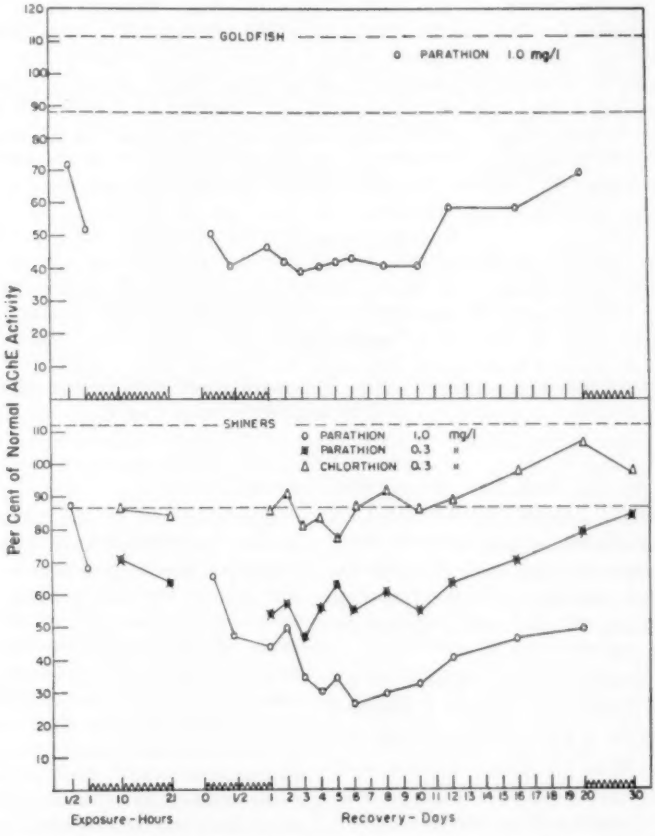

FIGURE 7.—Changes in AChE activity of shiners and goldfish during exposure and recovery periods.

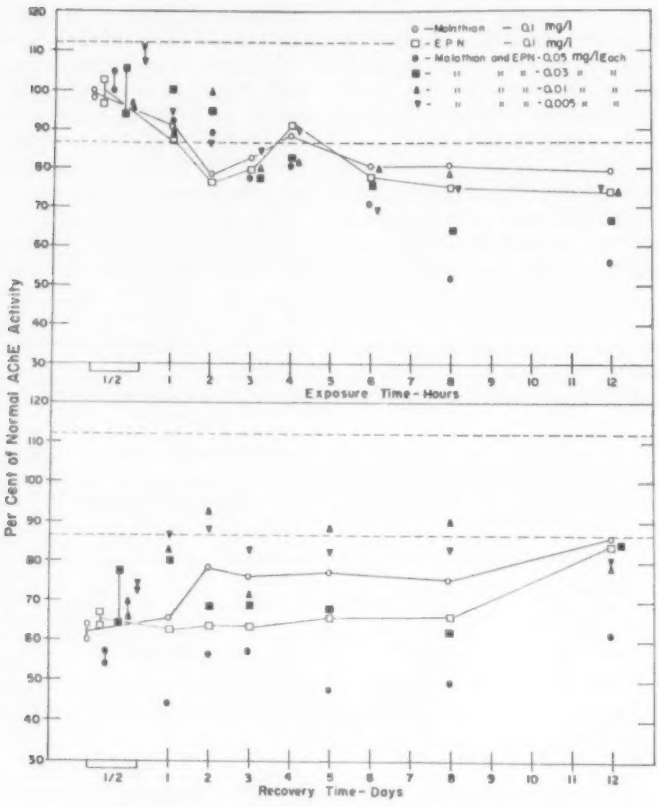

FIGURE 8.—Synergistic effects of malathion and EPN on the AChE activity of shiners.

normal by the 20th day of recovery. The shiners exposed to 0.3 mg/l of parathion showed a similar curve after the exposure period, with delayed recovery not starting until the 10th day and reaching 85 per cent of normal by the 30th day.

The reaction of the shiners to 0.3 mg/l of Chlorthion showed a minimal initial effect, a slight but continued depressant effect on AChE activity continuing to about the fifth or sixth day, and then regeneration and persistence above the lower limit of the range of normal variation.

Synergism

Combinations of the organic phosphorus insecticides have been used in instances where resistances to single compounds have been observed. One such combination with reported synergistic effects against insects is malathion and EPN (8). To examine the reaction of fish brain AChE to this combination, shiners were exposed to several combinations of concentrations of malathion and EPN (Figure 8). Both compounds were used alone at 0.1 mg/l and in various combinations of concentrations which in their sum did not exceed this value.

The AChE activity of shiners exposed to 0.1-mg/l concentrations of either malathion or EPN was similar; the activity dropped below the lower limit of the normal range after 1 to 2 hr of exposure but did not persist there until after the 4th hr of exposure. Following 12 hr of exposure the AChE activity of the shiners was about 75 to 80 per cent of normal. In very striking contrast, after 12 hr of exposure all combinations of malathion and EPN had produced equivalent or greater reduction in AChE activity. Brain-enzyme activity equivalent to that produced by exposure to 0.1 mg/l of the compounds alone was obtained with combinations of 0.005- and 0.01-mg/l concentrations. The combinations of 0.03- and 0.05-mg/l concentrations respectively reduced AChE activity to 65 and 55 per cent of normal.

In the 12-day recovery period, the maximum effect of the 0.05-mg/l combination persisted and reduced AChE activity to as low as 45 per cent of normal. By the 12th day, the fish exposed to the uncombined compounds had recovered to the lower limit of the normal range, whereas fish exposed to combinations were either just at this limit or below it. Fish exposed to the 0.05-mg/l combination had recovered to only about 62 per cent of normal. The synergistic effect of malathion and EPN in combination was markedly demonstrated.

Discussion

The presence of organic phosphorus insecticides in water has been shown to produce a specific reaction in the activity of brain acetylcholinesterase of exposed fish. The degree of depression of AChE activity is related to the concentration of the inhibiting compound, its specific nature, and the degree of exposure. The degree and extent of response to the AChE-inhibiting substances is also an apparent function of fish species.

Removal of fish from exposure and transfer to fresh water permits regeneration of the brain acetylcholinesterase. The amount of time necessary to attain normal levels of brain-enzyme activity is a function of the degree of the initial inhibition and is significantly characteristic of the specific insecticide. In some cases, such as for malathion, both the initial inhibiting effect and recovery are very rapid. In contrast, exposures to parathion produce in the same period of time a lesser degree of inhibition but in this case inhibition continues after removal from the contaminated water. The continued inhibition of AChE activity by the post-exposure reaction of parathion may lead to death or to a maximum level of inhibition several days after the actual exposure. Recovery periods may be as long as 40 days, depending on the initial degree of exposure, the insecticide, and species of fish. In the period of sub-normal AChE activity, the fish are obviously more sensitive to repeated exposures to AChE-inhibiting materials.

The specificity of the reaction between the organic phosphorus insecticides and fish-brain AChE permits the use of the fish as both an identifying and integrating mechanism for demonstrating the presence, immediate or for several weeks past, of these compounds in the aquatic environment.

The use of small fish to assess the hazard of organic phosphorus insecticides in water permits a direct evaluation of toxicity by *in vivo* action. The technique not only establishes the hazard to the inhabitants of the aquatic environment, but it also permits demonstration of the presence of the hazardous material prior to any lethal response by the fish. The response of a specific enzyme system to the organic phosphorus compounds permits identification of the specific class of compounds as well as a procedure for assessment of sub-lethal effects.

By continuous exposure to low concentrations of organic phosphorus in-

secticides the cumulative effect of these compounds on the acetylcholinesterase system can be evaluated and used as an index of residual contamination beyond the limits of chemical assay. The study of the *in vivo* response of the fish also permits assessment of residual effects during the post-exposure or recovery period and permits comparison of the relative hazard of the various organic phosphorus insecticides.

Conclusions

1. Fish-brain acetylcholinesterase is inhibited *in vivo* by organic phosphorus insecticides in dilute aqueous solution.

2. The degree of inhibition is a function of concentration of the insecticide, extent of exposure, and specific chemical nature of the inhibiting substance.

3. Fish removed from exposure to AChE-inhibiting insecticides demonstrate a capacity for regeneration of this enzyme.

4. The time required to regenerate the brain acetylcholinesterase to normal levels will depend on the extent of the initial inhibition, the specific nature of the compound which produced the inhibition, and the particular fish species. The regenerative period may be as long as 40 days and in some cases, longer.

5. Of the compounds examined only parathion produced in exposed fish a continued decrease in AChE activity after removal from direct exposure. In some cases the decrease continued and in others the brain-enzyme activity was maintained at a low level for as long as 10 days during the recovery period.

6. Post-exposure changes in brain AChE are, in part, a characteristic of the fish species. For example, bluegills exposed to Guthion showed immediate increase in brain-enzyme activity in the recovery period, reaching normal levels in 8 to 10 days. On the other hand, largemouth bass exposed in a similar fashion to this compound showed a 10-day lag before brain-enzyme activity started to rise and normal levels were still not attained by the 20th day of recovery.

7. Malathion and EPN when used in combination exhibit a marked synergistic effect in their anti-acetylcholinesterase property as measured by the *in vivo* reaction of AChE in the fish brain.

8. The specific *in vivo* response of fish-brain acetylcholinesterase to low concentrations of organic phosphorus insecticides permits assay of current or past pollution by these substances.

Acknowledgments

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This investigation received financial support from the North Carolina State Stream Sanitation Committee and was supported in part by a research grant, No. RG-4839, of the U. S. Public Health Service. Contributions of organic phosphorus insecticides were made by the Communicable Disease Center, Technical Development Laboratories, U. S. Public Health Service, Savannah, Ga.; Chemagro Corp., and Hercules Powder Co. Acknowledgment is made of the considerable cooperation of the Fish and Wildlife Service Hatchery at Hoffman, N. C., in supplying largemouth bass and bluegills for exposure tests.

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V. M. EHLERS

V. M. Ehlers, Past President of the Federation, died recently in Austin, Texas, at the age of 74, after a long illness. He served as Federation Vice-President in 1947–48 and as President in 1948–49. His more than 30 years of devoted service to the Federation was climaxed in 1957 when he was made an Honorary Member.

As one of the "Committee of One Hundred" he helped organize the Federation. During the course of his long membership, he contributed much to various committee work and always gave his best to the Federation. He was a charter member of the Board of Control, on which he served continuously from 1928 to 1942.

Mr. Ehlers was educated in the public schools of LaGrange, Texas, and was graduated from Texas A & M College in 1905 with a BSCE. In 1910 he received his professional engineering degree from Cornell University.

After several years as a construction engineer he became the first Sanitary Engineer for the state of Texas in 1915, a position he held with distinction until his death. As part of his work he helped organize the Texas Water and Sewage Works Association, with a Sewage and Industrial Wastes Section affiliated with the Federation, and was its continuing Secretary until his death. His outstanding service to the Texas association led to the Bedell Award in 1949.

Mr. Ehlers was the author of several sanitary engineering textbooks. He also was the founder and guiding genius of the Texas Water and Sewage Works Association Short School, one of the oldest and largest in existence.

He was a pioneer member of many technical and professional organ izations, and was a lecturer at many universities and colleges.

The public health field, in particular the sanitary engineering profession, has lost a great leader. All those who have come in contact with Mr. Ehlers will miss his drive and leadership in the many endeavors which he influenced.

THE OPERATOR'S CORNER

MANDATORY OPERATOR CERTIFICATION IN MICHIGAN *

By Donald M. Pierce

Chief, Section of Sewerage and Sewage Treatment, Division of Engineering, Michigan Department of Health, Lansing, Mich.

Any program imposing conditions of employment must have acceptance and support from both employer and employee to be successful. It must pay recognizable, tangible dividends to both groups. Opposition from either group, even if mild and unorganized, tends to dilute the program's effectiveness and value.

It is the purpose of this discussion to demonstrate that mandatory certification of all persons in responsible charge of sewage treatment works in Michigan is not only generally accepted but that it pays big dividends to the operator and the public he serves.

Voluntary Certification

Early Attempts to Require Certification

Certification of sewage works operators in Michigan began as a compulsory action in June 1934. At about this same time, the water works operators first formulated their certification plan. Both plans were based on rules and regulations of the State Health Department which required all persons in responsible charge of the plants to obtain certificates of competency from the State Health Commissioner.

After about three years, one of the operators affected by the requirements of the certification plan questioned whether the State Health Department had statutory authority to issue rules and regulations restricting employment in this manner. In May 1938, the Attorney General issued an opinion from which the following is quoted:

> It is our opinion that the rules and regulations under consideration are not supported by statutory authority . . ., and that it is necessary that the power to license, which deprives individuals of the right to employ and to be employed without restriction, must be delegated in no uncertain terms (by the Legislature).

This setback was softened by a strong expression of support for the program by many sewage treatment plant operators and the Michigan Sewage Works Association. For these reasons it was decided to proceed with certification on a voluntary basis and to support legislation which would make certification mandatory. Rules and regulations governing the voluntary certification of sewage treatment plant operators were placed in effect in November 1940.

Amendments were introduced in nearly every succeeding legislature but

* Presented at the 31st Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; Detroit, Mich.; Oct. 6–9, 1958.

were not enacted until 1949 when the entire statute governing water and sewerage works was completely revised and modernized.

Progress and Support

Operators certified during the period of voluntary certification generally were superintendents in the larger plants. Their education and experience usually exceeded the minimum requirements. Most, if not all, of these individuals wanted to obtain tangible recognition of their qualifications. They were proud of their job and anxious to protect it from incompetents. They were ready to provide leadership and encouragement to others who held similar values. Their performance and leadership brought recognition and support from municipal officials, consulting engineers, and the public they served.

Gradually, opposition and indifference were replaced with support and interest. The shift operator and others with limited training began to prepare for certification by means of observation, self-study, and formal training. In Detroit, the Civil Service Commission adjusted its promotional advancement program to require operators, chemists, and other groups in responsible positions to obtain a certificate of competency. Many communities, of course, continued to ignore the voluntary certification program, retaining superintendents and other responsible personnel lacking in qualifications. That such practices discouraged cooperation by other towns and other potentially good operators is generally recognized. However, it seems equally clear that the support for a full-fledged mandatory program of certification engendered during these years would not have developed without a testing period.

Transition from Voluntary to Mandatory Certification

Grandfather Clause

The statute requiring certification became effective during September 1949. Three years were required to establish supplementary regulations. This long delay was created not so much by the mechanics of preparation, legal phrasing, and routine approvals as by the inability to devise an acceptable "grandfather clause." Joint legislative committees of two legislatures had come and gone before the final draft was approved. The regulations governing the certification of sewage treatment works operators were published in the Michigan Administrative Code in October 1952.

In the language of the statute: Section 3(b) of Act 219, P.A. 1949;

> The state health commissioner shall classify sewage treatment works with due regard to size, type, location and other physical conditions affecting such works and according to the skill, knowledge, experience and character that the person in active operating charge must have to successfully operate said works, so as to prevent the discharge therefrom of deleterious matter capable of being injurious to the health of the people or to other public interests. The state health commissioner shall examine persons or cause them to be examined as to their qualifications to operate such works. He shall with the concurrence of the state council of health make and declare rules and regulations regarding the classification of such works, the examinations for certification of operators for such works and the issuance and revocation of such certificates, and shall issue and revoke certificates in accordance therewith. Every sewage treatment works subject to the provisions of this act shall within 30 days after the effective date of this act, or within such longer periods as the state health commissioner shall prescribe, be under the supervision of a properly certified operator: Provided, however, That nothing herein contained shall prevent governmental agencies, corporations, partnerships and individuals from continuing to employ in such

capacity any persons now in responsible charge of the operation of a sewage treatment works: And provided further, That nothing herein contained shall require the employment of a certified operator in a waste treatment works receiving exclusively wastes not potentially prejudicial to the public health.

Each municipality was given the opportunity to identify the person in its employ eligible to receive a certificate without examination. This person was to be officially designated by the governing body or owner as the one in responsible charge of the sewage treatment works on the date the statute became effective or in responsible charge of a plant which was started or completed shortly thereafter but within specified time limits. The definition of person in responsible charge did not permit anyone other than the resident superintendent to qualify. By this definition some municipalities found they did not have any person eligible for certification.

Certificates issued under the "grandfather clause" were limited in that they were valid only in the plant where the recipient was employed. This limitation was instrumental in influencing recipients to qualify later by examination.

A total of 95 limited certificates were issued. Out of this group 65 persons are still employed at treatment works and 28 of these have been successful in obtaining certificates of competency. Over half of the remaining 37 have shown keen interest in establishing their qualifications. Some are successful each year.

Voluntary Certificates Validated

The regulations adopted in 1953 retained the system and schedules for evaluation of qualifications which had been in effect under the voluntary certification plan. The one exception was to add a Class D category for the smallest plants. Accordingly, the State Health Commissioner, on recommendation of the Board of Examiners, issued certificates of competency to all persons who had previously earned a certificate under the voluntary plan and who were still actively engaged in sewage works operation. Thirty-three certificates were issued on this basis.

Mandatory Certification

Acceptance of Program

The degree of acceptance of a certification program can be evaluated only in general terms. Nevertheless, certain indicators can be measured with fair accuracy. Among the indicators of operator acceptance are: the number of operators taking certification examinations; attendance at training courses; enrollments for short courses and correspondence schools; membership in the appropriate sewage and industrial wastes association; subscriptions to technical journals; performance of laboratory analyses and preparation of operation reports; improvements in operational and public relations methods and results. Some of these trends are measurable. Others which are not measurable are no less real or significant.

Acceptance of such a program by the employer is more easily recognized even though he has fewer ways to express his attitudes. His acceptance, usually interpreted through an official, may be expressed by: salary increases to those obtaining a certificate; upgrading the superintendent of the sewage treatment plant to a higher level in the organizational structure; requiring operators below the grade of superintendent to become certified in order to qualify for the job; approving attendance of the plant staff at training meetings; payment of dues and subscriptions to technical societies and journals; prompt replacement of a retiring or deceased certified superintendent by another equally qualified man; and other similar action. An

excellent indication of general attitude throughout the state may be observed when a municipality employs a certified superintendent and staff to operate a newly built plant.

Growing Interest of Operators in Certification

Distribution of Certificates

Under the voluntary plan, applications for examination were submitted largely by individuals with qualifications generally above the minimum. During the last four years an increasing number of shift operators and others possessing a minimum of experience and formal education have sought to be certified. Some indication of this trend may be noted from Table I. In Class B half as many shift operators as superintendents have been certified. In Class C nearly half of the total number certified occupy positions other than superintendent.

TABLE I.—Distribution of Certificates by Employment Classification

Position	Class			
	A	B	C	D
Superintendent	30	38	51	11
Chemist	10	4	5	—
Supervisor	10	4	1	—
Shift operator	—	19	31	4
Other	—	6	7	2
Total	50	71	95	17

Early Application for Certification

In many cases shift operators and others submit applications to the Board of Examiners while they are still deficient in experience. Others, realizing their applications cannot be approved, wait another year before applying. Generally, about 20 per cent of all applicants are deficient in experience as shown in Table II.

Continuing Education

Analysis of the educational qualifications of all persons certified since the inception of the program reveals that many persons in each class possess educational qualifications substantially above the required minimum. It also shows that in each class the formal education of several of those certified would have been substantially less than required had it not been for the supplemental education these individuals acquired. It is significant to note the large number of persons supplementing their formal education by correspondence courses and short courses of a wide variety and scope. Some idea of this trend may be obtained from Table III.

TABLE II.—Reasons for Rejection of Applications during 1956

Item	Class of Exam			
	A	B	C	D
Number applying	15	31	72	6
Deficient in experience	5	4	16	0
Deficient in education	1	0	0	0

Attendance at Training Meetings

Records of attendance at training meetings conducted annually by the Engineering Division of the State Department of Health contain the names of over 500 persons who have attended these two-day sessions during the five years the mandatory certification pro-

TABLE III.—Accredited Supplementary Education According to Operator Classification

Class	Correspondence Courses	Short Courses
A	10	13
B	12	18
C	14	25
D	1	5

gram has been in effect. Operators at all levels of responsibility, certified or not, come to these meetings year after year. Each year nearly half of those attending have not previously attended. The majority of this group is interested in becoming certified or in obtaining a certificate in a higher classification.

Interest In Technical Literature

Another indication of interest is the continual increase in subscriptions to technical journals. Membership in the Michigan Sewage and Industrial Wastes Association has increased from about 135 in 1945 to over 575 in 1958. FSIWA manuals of practice and other technical bulletins and books are purchased by an increasing number of persons each year.

Repeated Attempts to Pass Examinations

The sustained interest in continuing to take examinations is evident from Table IV. This trend is repeated year after year.

TABLE IV.—Analysis of Failures of Written Test Related to Failures of Previous and Subsequent Tests

(a) Class C Test, Feb. 1957	
Total taking test	56
Failures (grade less than 60%)	24
Failures with grades between 50 and 60%	14
Failures who also failed previous Class C test	5
Feb. failures taking Dec. 1957 test	12
(b) Class B Test, Feb. 1957	
Total taking exam	37
Failures (grade less than 60%)	29
Failures with grades between 50 and 60%	20
Failures who also failed previous Class B test	8
Feb. failures taking Dec. 1957 test	14
Failures possessing Class C certificate	9*

* Includes 3 who failed previous Class B test.

TABLE V.—Plants Performing Routine Laboratory Analyses

Ownership	No. of Plants Performing Tests		
	Solids, BOD, etc.	Chlorine Residual Only	None
Municipal	136	16	15
Industrial	16	2	1
Institutional	7	1	1

Upgrading to Higher Class Certificate

Each year a large percentage of persons who are not successful in the written examination for Class B possess only minimum qualifications in either education or experience or both. This group is composed largely of shift operators whose experience consists of a few years in a single plant. As their experience increases and if they continue to study, attend meetings, and otherwise apply themselves seriously to the job, they normally have success in acquiring a Class B certificate. Those who do not work hard normally fail.

Increased Laboratory Work

The majority of treatment plants constructed since 1950 are equipped with laboratories that are in keeping with the particular needs of the plant. While many of the plants serving populations greater than 5,000 were similarly equipped prior to 1950, a large number of small plants lacked facilities largely because the plant superintendent had neither the interest nor the knowledge and skill to perform the necessary tests. Now, most of these plants have laboratories and testing is carried on regularly.

As of August 1958 there were 195 plants in the state above the level of septic tanks, or very small Imhoff tanks. Table V shows that of this total only 17 plants fail to perform any type of laboratory test and at 19 plants the only record maintained is

that of the chlorine concentration in the plant effluent. The remaining 159 conduct analyses routinely and regularly for solids, BOD, and a wide variety of other determinations requested by the State Health Department. Monthly operation reports are submitted regularly by this group to the Department.

At more than 50 of these plants, operating data are analyzed and interpreted. Much of this information is exchanged with other operators at meetings and through the State Health Department. During the past year special studies have been undertaken in about 55 plants on digester performance, quality of sludge and supernatant, and other related subjects.

It seems significant that of the 17 plants conducting no laboratory analyses, only one has a superintendent certified by examination. Superintendents of 15 of these plants were retained under the "grandfather clause."

Growing Interest of Employers in Certification

Early Recognition

The tremendous progress made by operators under the mandatory certification plan could not have been achieved without acceptance of the program by municipal officials. The favorable impressions made by operators certified under the voluntary plan during the late thirties and through the forties paved the way for the accelerated program of the past five years. The employers' acceptance or willingness to comply with the mandatory requirements of the statute changed to active support as the program continued to pay dividends in improved performance, sound administration, and better-than-expected public relations.

Higher Operator Salaries

Salaries and wages of certified operators have increased sharply during the past five years. It has been estimated conservatively that after certification salaries of operators in responsible charge of sewage treatment plants have advanced at least 50 per cent. This fact is a powerful incentive for certification as well as a potential hazard. For if operators do not justify their salary increases by high-quality performances they cannot expect the support and respect of employers or contemporaries in the public works family.

Conformity with Certification Requirements

A raise in pay is often difficult for the city official to justify, particularly when it unbalances his wage schedule for others in similar positions in water, streets, and other public works departments. In spite of these problems acceptance of an adjustment in salaries is general.

Basically, however, conformity with certification requirements is almost complete throughout the state. Of the 167 municipal plants mentioned in Table V, 127 have certified superintendents. At 33 others, the superintendent was retained under the "grandfather clause," leaving only 7 not complying with the statute. Arrangements are being made in each of these 7 communities to obtain a certified operator.

Encouragement to Operators

Compliance with the statute does not tell the complete story, however. Many activities of the operator would not be undertaken if city officials did not offer encouragement and assistance. When the plant superintendent and others of the operating staff attend a meeting, training or examination session, or short course, ex-

penses nearly always are paid by the municipality. Dues to technical associations and subscriptions to technical journals are generally paid by his employer.

Perhaps more significant is the growing popularity of incentive pay to operators at levels below superintendent when they receive a certificate of competency. Each year the Board of Examiners is urged by several examinees to speed up grading of the examinations so they can qualify for an automatic raise.

Early Employment of Operator at New Plants

In the majority of communities the search for a certified operator to become the plant superintendent begins several months to a year before the plant is completed. Most of them employ the superintendent and have him on the job at least three months before the plant is ready for operation.

Interest of Industry in Certification

Sewage treatment plants owned and operated by industry to serve their own personnel are not considered as coming under the purview of the statute requiring operator certification. However, industry plants of any substantial size and importance have voluntarily employed certified superintendents. Inducements and incentives to these employees generally are similar to those offered by the municipal employer.

Similar action, interest, and support have been shown by all state institutions which operate treatment plants.

Role of the Regulatory Agency

Leadership

The success of a certification program of this kind fundamentally depends on strong leadership by the state regulatory agency exerted in an atmosphere of mutual respect and confidence. This confidence and leadership must be accepted and well recognized from the very beginning, even while the plan itself is being formulated. Later, when the plan has become a legal requirement it must be nurtured and developed with understanding and appreciation of the problems of others. Above all there must be common objectives and purposes so that each of the three groups will desire to make the program effective.

Training

The regulatory agency should organize and promote a program of training for operators on a continuing basis. Where possible, assistance and cooperation in developing this program should be secured from the appropriate sewage and industrial wastes association and the educational institutions. Training should be provided in many forms to satisfy the needs of the total operator group. Providing information to the employer through such persons as the city manager, public works superintendent, and members of city councils is an important part of this educational process.

Encouragement and Assistance

Encouragement of operators to do a better job of operation, maintenance, laboratory analysis, record keeping, and public relations pays dividends in improved performance. The regulatory agency staff should visit each plant often enough to be familiar with plant problems and progress. Interpreting deficiencies or needed improvements in plant facilities and performance in the light of their effect on water quality gives direction and purpose to the program.

Examinations

Probably no single function in the certification process is as difficult or important as the examination of operator qualifications. To apply the techniques of examination to a group with such a varied background and with so varied a set of necessary quali-

fications requires an intimate knowledge in so many specialized fields that the combined efforts of several persons are usually required on the Board of Examiners. It is not enough to determine whether the applicant possesses knowledge of plants and processes. He must be tested also for familiarity with the legal and administrative aspects of plant operation, his ability to get along with and supervise others, his understanding of laboratory techniques, and his ability to make certain types of mathematical calculations.

The examinations should be varied from year to year to prevent anticipation by the applicant. Insofar as practicable there should be an interchange of examination questions and grading systems between states so that reciprocity may be granted without loss of effectiveness of the examination process.

Insistence upon Compliance

Uniform enforcement of the requirements of the statute has been found to be essential to the successful administration of the mandatory certification program in Michigan. Many municipal officials have pleaded their case for employing an uncertified person as the plant superintendent. Many others have found good reasons for continuing delays in filling a vacancy requiring certification. To permit deviation from these requirements would lead quickly to a succession of similar requests until the entire program would fail.

The program must, of course, be administered reasonably and fairly to permit communities and operators sufficient time to comply with requirements. On the other hand, recalcitrants must be dealt with promptly. This approach has been instrumental in achieving the complete compliance outlined in the foregoing. It is readily apparent that enforcement alone cannot assure acceptance and compliance, but without it the cooperation, assistance, and educational approach will be much less effective.

Dividends from Mandatory Certification

Dividends to the Public

The general public, including the taxpayer using the stream into which the plant discharges its effluent, derives benefits in many forms from operation of plants by certified operators. High-quality operation and maintenance of the plant, early detection of needed repairs and replacements, and timely anticipation of plant expansion or improvement can be expected only from highly qualified operating staffs. By substantially elevating levels of performance in Michigan plants, much greater protection is given the streams affected by plant discharges. All forms of recreation involving use of these waters become more enjoyable and fruitful. The lower riparian owner gets a tangible dividend of some magnitude from skilled management of this kind.

It is not difficult to imagine the bad effect on the state's tourist business if sewage treatment plants were operated today by persons deficient in qualifications. Michigan, like many states, depends heavily on its streams and lakes to attract the tourist. Great financial loss and deprivement of reasonable enjoyment and use would result eventually from lowered plant efficiencies.

Dividends to the Operator

Certification opens up many opportunities for the certified operator. Financially, his dividend comes in the form of substantial increases in salary. Job security based on satisfactory performance not only enhances his financial status but gives him the opportunity to become a permanent, valued member of the community.

VOLUNTARY OPERATOR CERTIFICATION IN FLORIDA*

By D. W. Jones and George T. Lohmeyer

Respectively, Director, Departments of Water and Sewers, North Miami, Fla., and Superintendent, University of Florida Sewage Treatment Plant, Gainesville, Fla.

Any certification plan for water and sewage treatment plant operators, whether voluntary or compulsory, must include provision for a training program. This program should be geared to meet the paramount needs of the operators and the types of plants in operation. Further, the training program should be handled to a large extent by the operators themselves. The program should be continuous and take into consideration the geographical nature of the area to be served.

In analyzing the progress made by Florida's voluntary certification plan, due credit must be given the training program. Undoubtedly, the success of the certification program in Florida is directly related to the fact that the first short school for water and sewage treatment plant operators was held at the University of Florida in 1930, 11 years before the certification plan was initiated. Since that time, operators have been extremely active in the training program as organizers and instructors.

A review of the voluntary certification program for plant operators in Florida must, by necessity, include a discussion of the organization which has officially sponsored the plan since its adoption, the Florida Water and Sewage Works Operators Association (FWSWOA). In fact, the Association's objectives, which follow, clearly indicate the importance of the licensing plan:

1. To advance the professional status of water and sewage works operators in the state of Florida;
2. To provide for a system of voluntary licensing of water and sewage works operators; and
3. To arrange for educational and training programs for water and sewage works operators.

History

In 1941, the Florida Water Works Operators Association was organized. Four years later the sewage works operators were admitted to the organization.

It is of the utmost importance to state that absolutely no feeling existed on the part of the organizers that the Association should be a union in any sense of the word. This philosophy prevails today. All have agreed that working conditions and the stature of the operator in his community could be improved, but such improvements, the Association feels, can best be achieved by cooperation and education. State regulatory agencies, consulting engineers, municipal officials, and representatives of industry have done much to promote and support the FWSWOA.

As part of the first constitution of the Association a voluntary certification plan was included. Early comments from some of the charter members indicated that the voluntary certification plan would be converted eventually to a mandatory plan after a sufficient number of plant operators had become certified. The exact number of operators was to have been a decision of the State Board of Health.

Certainly, the voluntary certification plan was not the main reason for forming the Association, but it did serve as a selling point during the formative

* Presented at the 31st Annual Meeting; Federation of Sewage and Industrial Wastes Assns.; Detroit, Mich.; Oct. 6–9, 1958.

period. This is revealed in a letter to prospective members from the first Secretary-Treasurer, R. D. Carnahan, who stated:

> We are hoping that, after careful study of the attached (voluntary certification) plan, you will feel, as so many of us do, that this is the greatest opportunity ever offered operators to better their working conditions and professional standing.

The certification plan and training program could never be described with fairness without giving full credit to the Bureau of Sanitary Engineering of the Florida State Board of Health. It would be difficult to measure the service the staff of that agency has provided in support of the FWSWOA, the voluntary certification plan, and the operator training program.

Seventeen years have elapsed since the voluntary certification plan was initiated in Florida. How is the plan administered? How is training provided to the plant operators? How has the FWSWOA assisted with the program? Has the status of the water and sewage works operator been advanced? What have been the weak points in the voluntary plan and how have they been remedied? Do the operators feel their voluntary certification plan offers more today than a mandatory plan?

Certification Plan

Administration

Over the years the FWSWOA has delegated to the State Board of Health a certain amount of responsibility in the administration of the certification program. For example: (a) The chairman of the examining board is the Director of the Bureau of Sanitary Engineering of the State Board of Health; (b) Each member of the Board of Examiners selected from the FWSWOA must be acceptable to the State Board of Health even though the Board acts only in an advisory capacity to the State Board of Health; (c) the State Board of Health prepares and grades all certification examinations; (d) the State Board of Health issues all certificates; and (e) the State Board of Health maintains a registry of certified operators in the state with an individual file on each operator.

It is altogether fitting and proper that the State Board of Health carry out essential functions of the voluntary certification program. Certainly a certificate of competency bearing the heading, "The Florida State Board of Health," will be shown greater respect by private, municipal, and state officials than a certificate headed, "The Florida Water and Sewage Works Operators Association." The words of one responsible official, after viewing one of the latter certificates, were: "This looks as if a bunch of water and sewage treatment plant operators got together and issued each other operation licenses."

Another reason for transferring more of the responsibility of administering the certification program to the State Board of Health was that the FWSWOA had neither the necessary funds, nor in its ranks, the necessary staff to administer the endless details of so great an undertaking.

At present, the State Board of Health has not yet officially graded plants as to complexity and size. Nevertheless, every effort is made to match plants with an operator of the proper certification level.

Acceptance of Certification

Such wide publicity has been given the voluntary certification plan in Florida that consulting engineers, city officials, and private developers normally confer with the State Board of Health in securing operation personnel. This is especially true for the new plants. In short, while Florida's operator certification plan is voluntary, it is felt the plan carries considerably more weight than the average voluntary certification plan because of the

work and influence of the health department.

In Florida both water and sewage treatment plant operators are certified under the same basic plan. The history of the voluntary licensing plan indicates clearly that this has been a wise and sound policy. This policy has been instrumental in fostering a spirit of cooperation and understanding in the field of water resources in Florida that is difficult to describe.

Numerous plant operators hold certificates in both water and sewage treatment plant operation. More than one experienced water works operator, upon transferring to the field of sewage treatment has found that operating a sewage treatment plant can be one of the most fascinating phases of sanitary engineering. Likewise, sewage works operators have developed a deep sense of appreciation of the men in water plants.

Operator Training

Planning Committee

The Florida Committee on Water Supply and Sewerage Education was organized before World War II. It is charged with the responsibility of developing an annual short school and other training methods. It is composed of representatives from each of the following state institutions and technical associations: Florida State Board of Health; University of Florida; General Extension Division (representing all institutions of higher learning); Florida Section, AWWA; Florida SIWA; and the FWSWOA.

The planning committee is an excellent cross-section of the sanitary engineering profession of the state and creates a strong liaison among all groups capable of offering assistance to the operator training program. Specifically, the committee does the following:

1. Continually evaluates the over-all operator training program in the state;
2. Makes all plans for a five-day annual short school held at the University of Florida;
3. Arranges for operator correspondence courses; and
4. Introduces new methods and improvements to old methods of operator training.

Wide publicity is given the conference and, by tradition, it is open to all who care to offer suggestions.

Annual Short Schools

Twenty-six annual short schools have been staged for water and sewage treatment plant operators in Florida. The five-day schools are held at the University of Florida with attendances consistently in excess of 200. This school is the culmination of the operator training program for the year and is the definite highlight for all of those able to attend. The University issues attractive certificates to all completing the school.

The school is open to all operators, regardless of experience and training. However, class work is arranged for the Class A and B levels only.

At the end of the course, 4-hr certification examinations are given to Class A and B applicants. However, it is pointed out that the purpose of the annual short school basically is not to prepare operators for these examinations. Rather, the school serves as a stimulus for self-improvement.

Not as a scheduled part of the annual short school but certainly of immeasurable value to the operators attending are the numerous "bull-sessions" which inevitably develop during the free periods. At such informal sessions operators gain much from their fellow operators and learn to respect the individual problems which surround each plant.

Another part of the school which has a direct bearing on the training and certification program is the annual operation awards banquet. At that time, the Florida State Board of Health

formally presents merit certificates for outstanding operation of water and sewage treatment plants. Each home town newspaper is provided with a press release and a picture of the award presentation. In selecting the award-winning plants, one of the judging points is whether or not the operator is certified.

Instructors at the annual short school are secured from the State Board of Health and the University of Florida, as well as from the consulting engineering firms. However, the present trend has been for advanced operators to provide at least one lecture during the school.

Correspondence Courses

The Florida Committee on Water Supply and Sewage Education realizes fully that the short school alone cannot possibly fill the entire training bill. Alert operators expressed an urgent need for correspondence courses designed strictly for plant operators which could be administered by the General Extension Division. As a result of this request three correspondence courses are now offered: "The Elements of Chemistry," "Basic Mathematics for Sewage Plant Operators," and "Basic Mathematics for Water Plant Operators." These courses are prepared by the University of Florida with the cooperation of the State Board of Health. Plans call for other correspondence courses to be added as the need arises on such subjects as plant maintenance, operation cost accounting, and stream sanitation. The correspondence courses have been effective operator-training aids. Recently the planning committee ruled that completion of these courses will be prerequisites for future Class A and B examinees.

Role of the FWSWOA

District Training

In spite of the excellence of the annual short schools and the favorable results from the correspondence courses, the FWSWOA leaders realized some five years ago that there were gaps to be filled in the training program. Too few operators could leave their plants for the one-week short course. Then, too, in 1953, the Class C level of instruction was dropped from the short school to add advanced training in the Class A level. New plants were being constructed at a very high rate and older plants were being enlarged. It was imperative, therefore, that some type of "regional" training be given in the field on the Class C level. It was also deemed essential that the operators should gradually assume a leading part in this program. To provide this training the FWSWOA reorganized into five districts so that its members could attack the training problems at the local level. Each district elects its officers and appoints committees to carry out the objectives of the FWSWOA. Friendly competition naturally exists between the districts.

Once a year each district holds a short course designed to meet the needs of the beginning operators of their particular area. Each school has an equivalent of about 24 hours of instruction, arranged to best satisfy the district members. For example, some districts hold night sessions over several successive weeks while others have found it more advantageous to schedule the course over three successive days.

The subjects covered have been standardized for the state. A district planning committee is responsible for arranging the details of the course. At the conclusion of each district short course, Class C level examinations are given to both water and sewage plant operators.

During fiscal year 1957, a total of 510 people attended these short courses. Also during this period, more than 100 operators passed the Class C examination.

In addition to district short courses, study groups are formed. In one district the members meet once a week for

review sessions using a standard sanitary engineering textbook. Other districts have used as training guides the syllabuses from the correspondence courses. One junior college teaches a mathematics course to plant operators. Some superintendents of larger plants carry on in-plant training for new operators from other plants in the district. Generally, the extent of training on the district level seems to be limited only by the ingenuity and enthusiasm of the district leaders.

District Meetings

District meetings are held monthly. Much has been accomplished by rotating these meetings among the communities of the district. Some meetings are held at community centers where members of the city government address the group. In this manner a closer relationship between the operators and other city departments is fostered. Usually, however, the meetings are held at a water or a sewage treatment plant with a conducted plant tour as the main item on the program. It goes without saying that the plant toured is also the plant inspected.

Newsletter

Even before the formation of the districts, the FWSWOA needed a means of keeping in touch with its members. As a result, the *Overflow*, a newsletter is published five times a year. Although the *Overflow* is officially published by the FWSWOA, publishing costs are now shared by the Florida Section of the American Water Works Association and the Florida Sewage and Industrial Wastes Association. The newsletter contains articles by operators and engineers on subjects pertinent to Florida. With respect to operator training, it lists in advance the schedule for district short courses, the annual short school, examination dates, the attendance at each course, and the number taking and passing each examination. In this respect the *Overflow* makes a major contribution to the training and certification plans for operators.

Voluntary versus Compulsory Certification

During the period of voluntary certification in Florida much has been accomplished for the plant operators who have participated in the program. Several cities now give automatic pay increases to men who move to higher classifications in the certification plan. More than one city now recognizes the grades of voluntary licensing in its civil service code. Rarely have operators lost their jobs through strictly political reasons.

While the average salary of the plant operator is not commensurate with his responsibility, a number of operators have gained salary increases by transferring to positions of greater responsibility or by improving the efficiency of their plants.

In spite of the definite gains made under the voluntary certification program there is a feeling on the part of the FWSWOA and others that a compulsory certification plan would be superior to the present system.

The big weakness in the voluntary plan is that the less competent operators have remained indifferent to certification and self-improvement. There remain too many plants which do not participate in the plan.

According to the February 1958 listings in the *Overflow*, 274 sewage and 340 water treatment plant operator certificates have been issued. The July 1958 *Overflow* lists a total of 242 sewage works and 527 water works in the state. This would mean that for every 10 sewage treatment plants there are about 11 certified operators and for every 10 water treatment plants there are about 6 certified operators. This is part of the record in a state which undoubtedly has one of the finest voluntary certification plans in the nation.

During fiscal year 1958 the

FWSWOA appointed a compulsory certification feasibility study committee. As a early reaction, it must be admitted that scattered members of the FWSWOA were suspicious of the terms "mandatory" and "compulsory." These suspicions were allayed by explaining the committee's work through articles in the *Overflow* and by arranging discussions on the subject at the district level. The final committee report, which has been unanimously adopted by the FWSWOA, states:

> This committee has studied the various aspects of compulsory certification for water and sewage works operators in the State of Florida and has concluded that a program of this nature is both desirable and possible.

The FWSWOA is now in the process of preparing a compulsory licensing bill for presentation to the legislature. Numerous details have yet to be worked out. But after 17 years' experience with a voluntary certification plan, the Association feels a legal plan can be achieved with a minimum of difficulty and delay.

Conclusion

The history of voluntary certification in Florida shows that much can be gained if the program is given wholehearted support by all groups and individuals interested in water and wastewater technology. Nevertheless, these gains, substantial as they are, fall short of the intended goals. In view of this, a switch to compulsory certification seems to be desirable.

OPERATOR CERTIFICATION—PANEL DISCUSSION *

I. VOLUNTARY CERTIFICATION IN WISCONSIN

By Thomas T. Hay †

Superintendent, Sewage Disposal Plant, Racine, Wis.

The initial support for a certification plan should have a broad base. This means that all groups which may have an interest in certification must be contacted and kept informed. Their support must be solicited. A municipality or industry may very easily come to suspect that a plan backed only by plant operators is solely for the operators' protection—and they may be right.

History

To illustrate the need for support from all sides the history of certification in Wisconsin is used as an example.

In 1935 the Conference of Wisconsin Sewage Works Operators formed a committee for certification. Through the efforts of this committee a bill was introduced in the state legislature to set up compulsory licensing. This took place in 1937 at the urging of the Conference. Before introducing the bill the League of Wisconsin Municipalities was contacted for support, but insufficient time was allowed for this organization to study the proposed legislation. As the League feared there was a possibility that such legislation might limit the functions of local government, they opposed the bill and were instrumental in its defeat.

In the following years many informal discussions were held on the subject of certification. Several times the

* In part from the transcript, 31st Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; Detroit, Mich.; Oct. 6–9, 1958.

† Panel leader.

Conference appointed committees to study and promote licensing. But it was not until the spring of 1955 that a committee was formed for the voluntary certification of sewage works operators. This committee held its first meeting on Oct. 25, 1955. This was 18 years after the original bill was defeated.

The committee for the administration of the plan was composed of the following: one faculty member from the University of Wisconsin, two members designated by the League of Wisconsin Municipalities, three sewage works operators designated by the Conference of Wisconsin Sewage Works Operators, and the Chief of Section on Environmental Sanitation of the Wisconsin State Board of Health.

From the beginning, this committee received excellent cooperation from all who would benefit from a certification plan. Within 18 months all sewage works were classified, operator qualifications were established, and administrative details were worked out. The first examination was held during Apr. 1957; the second in Dec. 1957; and the third in Apr. 1958. At least one examination is to be held each year.

In developing the certification program, the committee had the opportunity of studying many plans in operation in other states. Thus the Wisconsin plan includes many items of demonstrated workability.

Results

Under this plan, 350 sewage treatment plants have been classified. In the first three examinations, 123 operators were certified. Eight of the men certified are employed at industrial waste treatment plants. Already, some municipalities are allowing only certified operators to be hired for certain positions. Another has started an incentive pay raise based on certification.

Discussion

Who should be certified? Some say only the person in responsible charge; others say all personnel; and still others say the answer is between these extremes. None will argue the need to have the head man at the plant certified, but differences of opinion are likely to develop when it is suggested that all personnel should be certified. Nevertheless, in Florida the number of plants staffed only by certified operators already exceeds 70.

At Racine, Wis., more than 60 per cent of the personnel holds certificates in some grade. It has been found that plant operation improves as the number of certified employees increases. Certification has encouraged a more thorough understanding of treatment. This makes the job more interesting to the men, which in turn produces better results.

An item which deserves much more attention than it has been given so far is training programs. Many of the certification programs require attendance at special training schools while others give credit for such attendance. This makes the specialized training school a part of the certification plan, yet most plans do not in themselves take on the responsibility for directing or supporting these schools. This year's report of the Federation's Operator's Qualifications Committee recommends realistic changes in this respect.

The reports of the committee on operator's qualifications have recommended compulsory certification. This is undoubtedly wise. But there is a definite place for voluntary certification. Voluntary certification can be put into effect by agreement among the parties concerned. It is not affected by legislative inaction. It can be the stepping stone to a compulsory plan.

Compulsory certification of sewage works operators must of necessity be set up at state levels. The responsibility of the Federation should be to help states organize plans which will result in uniform requirements throughout the country and to encourage and assist in training programs.

II. CERTIFICATION IN THE PACIFIC NORTHWEST

By Roy C. Jones, Jr.

Maintenance Superintendent, Sewage Disposal System, Portland, Ore.

Oregon is a child among the states having certification programs. The voluntary plan in operation there is only three years old. Still, it seemed that sufficient time had elapsed to measure Oregon's reaction. It also seemed desirable to learn more about reaction to certification in the nearby states.

In an attempt to measure the results of certification, 10 questions were asked a number of individuals in British Columbia, California, Idaho, Oregon, and Washington. The questions, replies, and comments are listed below.

Questions and Answers

1. Do you feel operators' certification is of benefit to you?

Of the 105 operators questioned, 6 said it was too soon to tell; 41 said "no"; and 58 said "yes." In other words, 55 per cent felt that they were gaining by certification. Oddly enough, this 55 per cent was composed almost entirely of Oregon operators.

2. In your opinion do you think all employees at sewage treatment plants should be certified or licensed?

Eighty-seven operators were queried and 22 answered "yes." Of the 15 city officials and 18 operating supervisors who were questioned, 4 of the former and 5 of the latter, replied "yes." There was a wide range of opinion on this question.

3. Would there be any advantage to you if certification were mandatory?

On this question, 89 of the 105 operators questioned said "yes." This response certainly indicates that mandatory certification is believed to be of greater benefit than voluntary certification. Of the 15 city officials who were questioned, 2 simply raised their eyebrows and gave no opinion whatsoever; 4 said "no comment"; and 5 said "yes." Of the 18 operating supervisors, 15 answered "yes."

4. If you are in charge of a sewage treatment plant, are you certified?

Twelve of the 18 operating supervisors answered "yes." Also, five city engineers were questioned because they gave direct supervision to treatment plants. One engineer was certified.

5. If you are a member of a governing body, do you investigate possibilities of obtaining certified operators before hiring treatment plant help?

Fifteen city officials were questioned and 13 said "no."

6. As a member of a governing body, do you encourage your operator to attend schools and conferences and the like so that he can qualify for certification?

From 10 of the 15 city officials questioned the answer was "yes." One said it was the first time he had ever heard of such a program. These results don't speak very well for our public relations efforts.

7. As a member of a governing body, have you received any benefit or better performance from your treatment plant since your operator became certified?

Again 10 of the 15 said "yes."

8. As an operator have you received any benefits from certification over what you may have experienced before?

Five out of 18 operators answered "yes." Now, to break this down a little bit further, these same five had received pay raises after certification; two said that since being certified they had been ordered to attend all council meetings and advise on any problem regarding the treatment plant.

9. As an operator, do you feel that certification and licensing would be advantageous?

Out of the 105 operators questioned, 54 said "yes" and the same 41 who said "no" in answer to Question 1 said "no" to this question.

10. Should certification be on a state-wide or national basis?

In 117 out of 120 cases the answer was "state-wide." However, it seems that these same 117 felt that minimum requirements in the various states should be uniform so there would be less difficulty with reciprocity.

III. COMMENTS ON CERTIFICATION

By Ernest Hamilton

Superintendent, Sewers and Sewage Treatment, Boulder, Colo.

It would seem today, with the cost of treatment facilities so high, there would be no hesitation to hire qualified operators. But many times this is not the case. Political considerations, lack of qualified individuals, and low salaries, singly or in combination, come into play and work against efficient sewage treatment. Fortunately, state-wide operator certification can prevent unreliable and uneconomical treatment. Certification, though, cannot be invoked overnight, it takes time and work.

Some states have started out with compulsory programs and others have made the transition from a voluntary plan. Still others find that a voluntary program alone is extremely beneficial. No matter what the final result, all successful plans have had a great deal of support before their first certification scheme went into effect. Out-distancing one's support can lead to trouble.

In Colorado, a quick trip to the legislature with a mandatory plan resulted in a disappointing set-back. Consequently, Colorado today does not yet have a plan in force. It is hoped that before too long voluntary certification will be in effect, but even the proposed voluntary plan still lacks the full support of the League of Municipalities.

Most work on certification must be done at the state level. However, this does not mean that assistance cannot be rendered at the national level. Moreover, there is a strong need for such assistance and the first step in getting this help is to support the work of the Federation's Operator's Qualifications Committee by keeping it informed of certification progress and developments.

TIPS AND QUIPS

For the Man Who Doesn't Have Everything

When you travel with children few sights are as pleasant as a clean-looking filling station. Now we have good news for parade-watching, agonized parents who are equipped with shoulder-sitting offspring—a mobile comfort station.

The unit is of all-aluminum construction and is made from corrugated truck skin and standard body sections. The station is 36 ft long, 8 ft wide, and stands 8 ft 9 in. high. Over-all

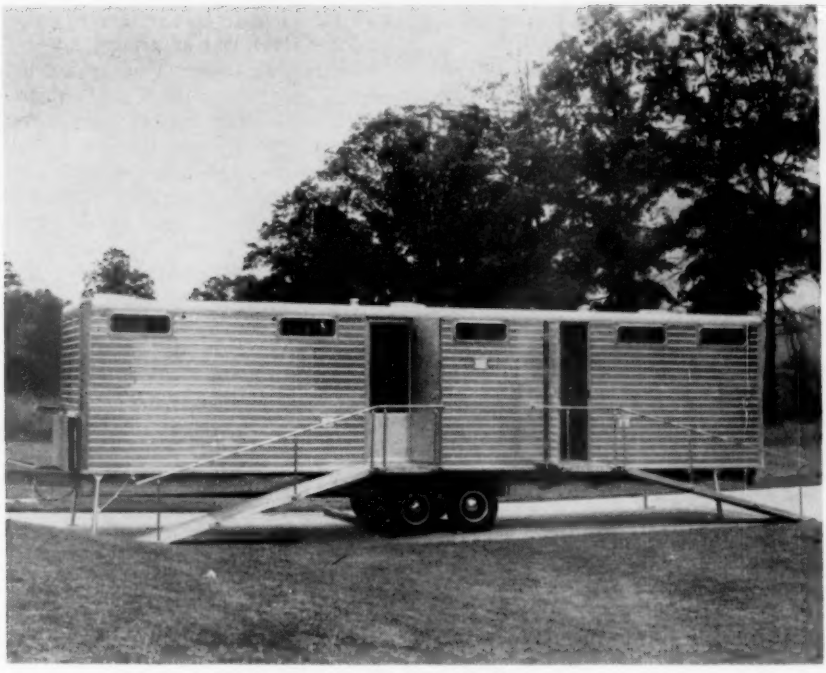


FIGURE 1.—Mobile comfort station.

height from the ground is 10 ft 6 in. (Figure 1). It weighs 12,000 lb.

With its own 550-gal water supply, the station can be placed in any location and accommodate 600 persons a day. It also can be connected to the municipal sewer and water systems. The station is lighted by connection to local power lines. A portable generator can be installed for use where power is not available.

The Fred S. Gichner Iron Works, Washington, D. C., manufactures the unit and it will be used by the National Park Service for parades and other large gatherings.

Explosion at Toledo

By noon on Dec. 9, 1958, the primary sewage treatment plant at Toledo, Ohio, was shut down to allow the contractor to install Venturi meters on the raw sludge lines and to connect piping in the basement of the digested sludge pumping station with piping from the new secondary treatment units.

On the afternoon of Dec. 10 the contractor's men working in the pipe tunnel under the clarifier control houses thought they smelled gas. A combustible gas indicator was borrowed from the treatment plant but no gas was found. However, as a precautionary measure no lead-melting pots were lighted.

At 7:40 PM, Dec. 10, an explosion completely demolished the No. 1 clarifier control house. Rubble was spread over a 100-ft radius. The second control house, located about 200 ft away, and the equipment in it also were badly damaged. All walls were cracked and some were blown out.

It is believed that sludge gas may have accumulated in the tunnel under the control houses when 5,000 gal of

raw sludge was drained to permit the piping connections.

Fortunately, no one was injured. Five minutes before the explosion two of the plant men passed through the control house on a routine inspection. At that time they smelled no gas.

Names Again

In the November 1958 issue we mentioned that the Virginia Association was in the middle of a change-the-name-of-the-Association contest. In a somewhat different vein we learned of an old name used for a new purpose. The old name—David B. Lee; the new purpose—a name for a sewage treatment plant.

At Eau Gallie, Fla., the new sewage treatment plant is called the David B. Lee Plant. A better name would have been hard to select for few individuals have devoted more energy to our field than Past President Lee. The only regret we have is that we wern't able to hear Dave express his pride and gratitude at the dedication.

Electroplating Wastes *

The degree of treatment which has to be given to plating wastes depends very much on the destination of the final effluent. Most of the compounds used in electroplating and metal finishing are poisonous and if discharge is to a river containing fish or to one which is used as a source of water supply, highly efficient treatment for substantially complete removal of these compounds is almost always necessary. If discharge is to a sewer, less complete treatment is usually required—sufficient to reduce the concentrations of contaminants to a level at which they will not damage the sewer, or be a danger to men working in the sewer, or cause interference with the biological and other processes used for treatment of sewage.

Sewers may be damaged by hot discharges or by strongly acid wastes; strongly alkaline wastes may cause formation of adherent deposits from hard waters. Soluble sulfates are known to attack concrete. Vapors of flammable solvents can cause explosions and toxic vapors of cyanides or of chlorinated hydrocarbons are a hazard to workmen. In the mixture of sewage and industrial effluents which ultimately reaches the sewage treatment works, most heavy metals in concentrations between 1 and 5 mg/l interfere with treatment of the sewage and the sludge separated from it. Cyanides in concentrations above about 2 mg/l have a detectable adverse effect on treatment of sewage even though cyanide can itself be biologically destroyed.

Satisfactory methods for treatment of all the common types of plating and metal-finishing wastes are now well known and consist of chemical methods involving one or more of the processes of neutralization, precipitation, oxidation, or reduction. Before treatment is undertaken it is worth examining the methods of working in the plating shop to see whether the quantity of water used can be reduced, for example, by using drag-out tanks or even counter-flow rinses, and whether anything can be done to reduce the loss of chemicals due to drag-out and spillages and in cleaning operations. A reduction in the volume of waste generally means that a smaller treatment plant is needed, and the quantity of chemicals required for treatment is, of course, directly related to the quantity of contaminants to be removed.

* *Notes on Water Pollution* (Dec. 1958).

Oblivion

Oblivion is full of people who permitted the opinions of others to overrule their belief in themselves.

Editorial

NAME AND DESTINATION, PLEASE?

"Your name and destination, please?" is a frequent question the air traveler must answer and the broad charges of the 1958 Board of Control meetings in Detroit could very well be summarized in a similar question to the Federation itself. As to destination, the Board of Control authorized expenditures for extending the public relations activities of the organization and professional advancement of Federation members. A vital part of this is consideration of the possibilities of an improved name for the Federation itself.

To name a newborn child is often vexing even for the parents and, unless names have been predetermined, considerable delay may occur unless action is forced by the laws of birth registration. The original name of the Federation, "Federation of Sewage Works Associations," was a "natural," and it served the organization very well for the first 20 years of its existence. Time brought industrial wastes interest in the organization to the point that "industrial wastes" was added to our name in 1950.

During the last decade, the feeling has often been expressed that the organization name should be shorter and that it would be improved if "sewage" were not included. Supporters of this latter suggestion point out that the word "sewage" is more frequently associated with disposal problems surrounding human excreta than with collection and treatment of *used* water from a variety of domestic sources.

Our name has also been criticized because of its lack of complete definition of the term "industrial wastes." The latter term is understood by many to denote any wastes from industry, whether they be solid, gaseous, or liquid. Indeed, the man on the street may think of these in this order rather than the reverse, which we all would prefer. In this connection, no one recommends doing away with "sewage" as a word but semantic developments during this time indicate the availability of both shorter and more generally acceptable terms for "sewage and industrial wastes."

A search of literature for an appropriate synonym for this term in its sense of used water or spent water is revealing. The GLOSSARY—WATER AND SEWAGE CONTROL ENGINEERING, published by the Federation and other organizations in 1949, defined "waste water" as water which contains contaminating waste products. This name has appeared frequently in the British and American literature. With the further simplification of combining these words to a single word *wastewater*, it may be used to denote "sewage and industrial wastes" as in the title of the Federation's revised Safety Manual SAFETY IN WASTEWATER WORKS. The use of this word as a single one is suggested as being simple, direct, palatable, and meaningful. It should be emphasized that it is not offered to supplant any other terms but to denote *used water* of domestic and industrial origin.

How does this fit into the possibility of a new name for our organization? Obviously, it can shorten the present name by the substitution of *wastewater* for *sewage and industrial wastes*. But is there more that can be done to the name that will make it descriptive and simple? An accepted definition for *federation* is an organization of associations, and this certainly fits. With

this definition, are both *federation* and *associations* necessary?

Should you classify the names of associations in the United States, you would note that most can be placed in one of three categories: (1) a professionally identified group, (2) a group devoted to a single cause, and (3) a group dealing with materials or products. The Federation does not have a single predominating professional group about which it may rally. It does pursue the cause for clean streams, though many Federation members dealing with wastewater collection systems only are much more mindful of their utilitarian services to each building than water pollution reduction in the receiving waters. All Federation members deal with the technical problems of wastewater collection (including pumping) and disposal (including treatment). Accordingly, it has been suggested that the combination *wastewater technology* fully encompasses the activities of Federation members and that it reflects the aims and objectives of the Federation.

A similar suggestion has resulted from thoughts which recognize, with complete propriety, our organization as the one dealing directly with the technical problems of water pollution. *Water pollution technology* is the resulting combination. It emphasizes the Federation's interest in clean waters and it also expresses our technical interest in it. *Water pollution* is a familiar term to the general public and a name including it is most deserving of consideration.

During recent months, the Federation Name Change Committee under the Chairmanship of Roy F. Weston has been considering this subject in complete detail. The committee is grateful for suggestions that have been made by all those who have sent them in, including several not on the committee and several wives of Federation members. While it is impossible to give the entire list of suggestions, a few are listed to indicate their range. These include Federation of Wastewater Technologists, Federation of Water Reclamation Associations, Water Pollution Control Federation, Wastewater Treatment Federation, Polluted Water Technology Federation, Wastewater Technology Federation, and Water Pollution Technology Federation. Others include Sanitation Federation, Hydrowaste Technology Federation, Natural Waters Improvement Association and the Federation of Alcidean Societies.

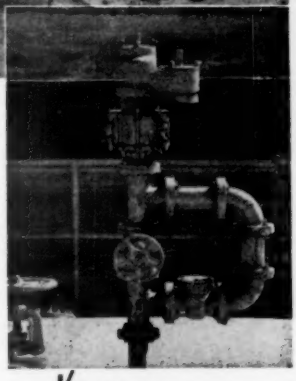
Perhaps it is the wealth of suggestions that has brought many to the feeling that the present name is satisfactory and that nothing need be changed. Those who say a change should be made feel that the proper change would be helpful to the organization in all its activities as well as to those affiliated with it. A possible advantage cited is the attraction of new men to the field and this is no small consideration.

The broad span of both professional and non-professional callings engaged in wastewater technology is in itself severely limiting in choosing a name that would be accepted by all. The Name Change Committee wants descriptive and simple names that the Board of Control can consider at the Dallas Federation Meeting.

What thoughts do you have on this? Do you feel the present name is satisfactory and that no change should be considered? If you feel a change should be considered, do any of the suggestions listed herein suit the need? If so, please state which names appeal to you or if you have others to suggest, please send your suggestions to the Federation office. All will be made available to the Name Change Committee and in this way to the Board of Control. This is an outstanding opportunity for you to voice your opinion in a most important Federation matter. Your comment may develop into a boost for yourself as well as your fellow members of the Federation. It will surely help determine the destination of your Federation!

R. E. F.

Photos courtesy Dorr-Oliver



SAFETY-ENGINEERED "Varec" SEWAGE EQUIPMENT at new Oxnard, California Sewage Plant

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S-16

Proceedings of Member Associations

NORTH DAKOTA WATER AND SEWAGE WORKS CONFERENCE

The 30th Annual Convention of the North Dakota Water and Sewage Works Conference was held at Dickinson, N. Dak., Oct. 8–10, 1958. The total registration reached 143.

Among the papers and discussions of particular interest to specialists in the wastewater field were the following:

"Dickinson Municipal Facilities," Panel Discussion.

"Public Works Planning," by W. E. Gilbertson, Deputy Chief, Sanitary Engineering Services, USPHS, Washington, D. C.

"Infiltration of Water into Sewers," by Lloyd K. Clark, Clark, Groff, and Cave, Salem, Ore.

"Lagoon Construction and Operation," Panel Discussion.

"Lift Station Construction and Design," Panel Discussion.

At the annual banquet the principal speaker was Harry Hanson, Director, Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio.

Officers elected for the year 1958–59 were:

President: Herbert Arnold, Williston.
Vice-President: Frank Orthmeyer, Bismarck.
Secretary-Treasurer: W. Van Heuvelen, Bismarck.

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(*Continued on page 202a*)

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NORTH CAROLINA SEWAGE AND INDUSTRIAL WASTE ASSOCIATION

The 1958 Annual Convention of the North Carolina Sewage and Industrial Waste Association was held in conjunction with the North Carolina Section, AWWA, at the Hotel O'Henry, Greensboro, N. C., November 10–12, 1958. A total of 355 members and guests were in attendance, including 54 women. This constituted a new record for the group.

Some of the highlights of the technical program, from the point of view of sewage and industrial wastes personnel, were the following:

"Automation in Water and Sewage Works," was discussed by W. N. Piatt, III, of Piatt and Davis and Associates, Durham, and W. G. Brown, Assistant Superintendent, Water and Sewer Department, Durham. Mr. Piatt pre-

(*Continued on page 204a*)

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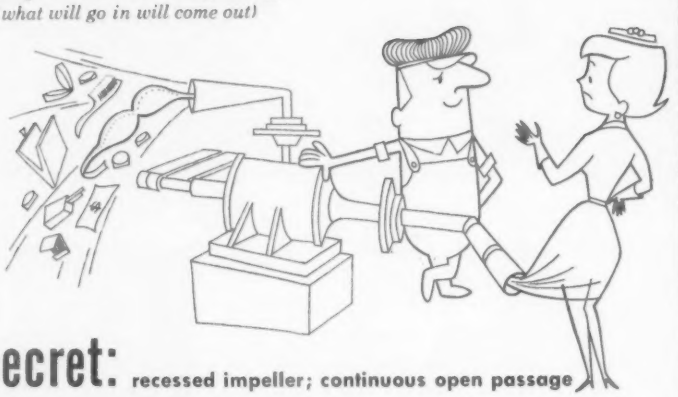

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sented the point of view of the designer and Mr. Brown the standpoint of the operator.

"Progress in Abatement of Water Pollution Under Public Law 660," was the title of a paper presented by C. H. Atkins, Regional Engineer, Region III, PHS, Charlottesville, Va.

"New Developments in Sludge Treatment and Disposal," were discussed by LeRoy W. Van Kleeck, Connecticut State Department of Health, Hartford, Conn.

"Catalytic Reduction Process of Accelerated Digestion," was the topic dealt with by Tom H. Forrest, Chicago Pump Company, Chicago, Ill.

L. E. Langdon, Pacific Flush Tank Company, Chicago, Ill., presented a paper on "P.F.T. Pearth Gas Recirculation System."

James E. Lineberger, Dorr-Oliver, Inc., Atlanta, Ga., discussed, "Densludge Process Thickener."

Kenneth S. Watson, FSIWA Past-President, extended the greetings of the Federation. He presented the Bedell Award, for extraordinary personal service to the North Carolina Association, to George S. Rawlins, Charlotte, and the Hatfield Award, for outstanding plant operation to John L. Brown, Jr., Kannapolis, N. C.

The following officers were elected for 1958–59:

Chairman: W. E. Long, Jr., Raleigh.
Vice-Chairman: R. E. Ebert, Winston-Salem.
FSIWA Director: L. S. Dukes, Charlotte.
Secretary-Treasurer: D. Y. Brannock, Burlington.

D. Y. Brannock,
Secretary-Treasurer

KENTUCKY–TENNESSEE INDUSTRIAL WASTES AND SEWAGE WORKS ASSOCIATION

The Annual Meeting of the Kentucky-Tennessee Industrial Wastes and Sewage Works Association was held jointly with the Kentucky-Tennessee Section of the AWWA at the Peabody Hotel, Memphis, Tenn., Sept. 22–24, 1958. Registration reached 366, a new record.

The program was a good one and interesting papers and panel discussions reached across the sewage and industrial wastes fields.

Officers elected for 1958–59 were:

President: C. Gordon Gaither, Lexington, Ky.
Vice-President: A. L. Strub, Union City, Tenn.
FSIWA Director (1961): M. A. Churchill, Chattanooga, Tenn.
Secretary-Treasurer: S. Leary Jones, Nashville, Tenn.

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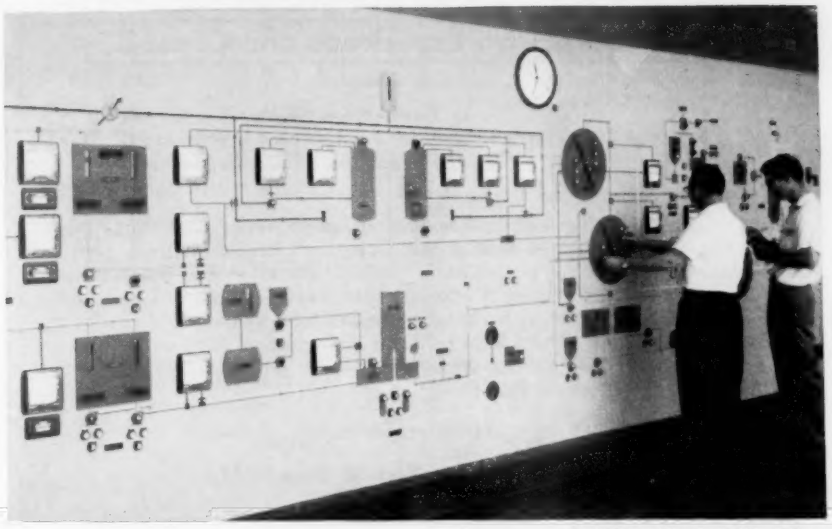

Central Graphic Control Panel for Boeing's Industrial Waste Treatment Plant. Panel includes controllers for flow and liquid level of various tanks, as well as recorder-controllers for the Foxboro ORP meters. **Consulting Engineers:** *Wilson & Company, Salina, Kansas.*

Foxboro continuous control system

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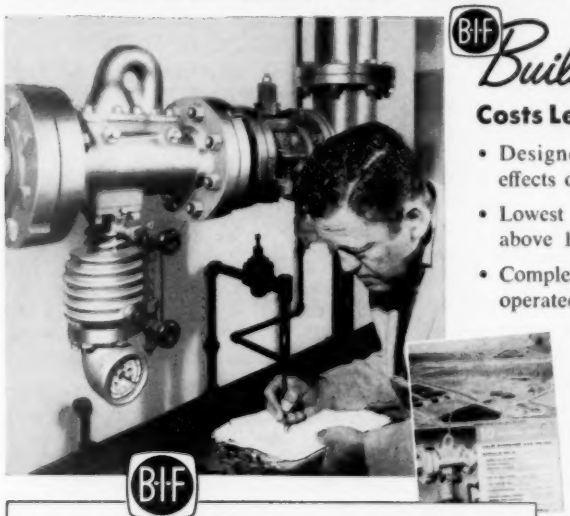

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FIGURE 1.—Dry chemical, portable fire extinguisher for control of liquid and electrical fires.

Automatic Control of Chemical Feeders—Bulletin B-I-F P7, from the Omega Machine Co., 345 Harris Ave., Providence 1, R. I., describes a number of methods of automatically controlling the concentration of chemical additives.

Thermometers—A 56-page catalog includes details of system thermometers, indicators, recorders, transmitters, and electric or pneumatic control instruments. Vapor actuated, gas actuated, and mercury actuated thermometers and thermal systems for use between the temperature limits of −125°F and 100°F are listed and explained, along with separable wells and other accessories.—Catalog C-60-2, Minneapolis-Honeywell Regulator Co., Industrial Division, Wayne and Windrim Aves., Philadelphia 44, Pa.

Liquid Level Controls—Floatless liquid level controls suitable for use in conductive liquids where the resistance does not exceed 20,000 ohms are described in Form No. 25, Charles F. Warrick Co., 1964 W. Eleven Mile Road, Berkley, Mich.

Pipe Couplings—The roll-grooved end method of quick-coupling lightweight pipe or tubing is detailed in a bulletin from Victaulic Company of America, P. O. Box 509, Elizabeth, N. J.

Lined Corrugated Pipe—A smooth lining for corrugated pipe is now available and called "Smooth-Flo" by Armco Drainage and Metal Products, Inc., Middletown, Ohio. Bulletin SF-12257 describes flow capacity, flexible strength, durability, installation cost, and size range.

Conversion Factors Chart—A wall chart containing conversion factors is available from Precision Equipment Co., 4411E Ravenswood Ave., Chicago 40, Ill.

Package Treatment Plant—Bulletin 26-S-92 gives details on the Sparger aerobic process designed for complete treatment of wastewater from populations of 100 to 2,000.—Walker Process Equipment, Inc., P. O. Box 266, Aurora, Ill.

Floodlights—Outdoor floodlights that are reported to stand up in rain, sleet, and snow—even when used face up—are described and priced in Bulletin P-109. The holders are equipped with seals of silicone rubber that hug lamps to help protect against vibration. The cast-aluminum line includes floodlights for medium mogul base reflector lamps up to 500w—Stonco Electric Products Company, Kenilworth, N. J.

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(Continued through page 216a)

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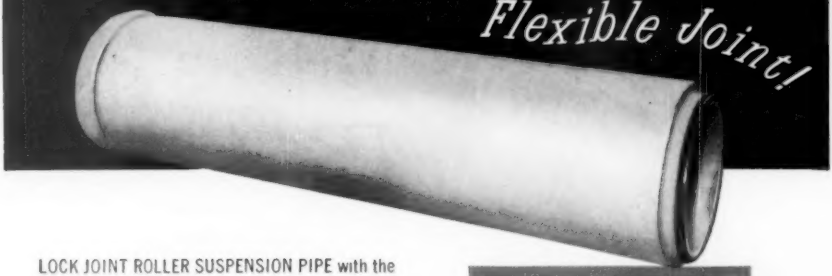

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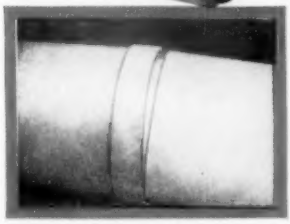

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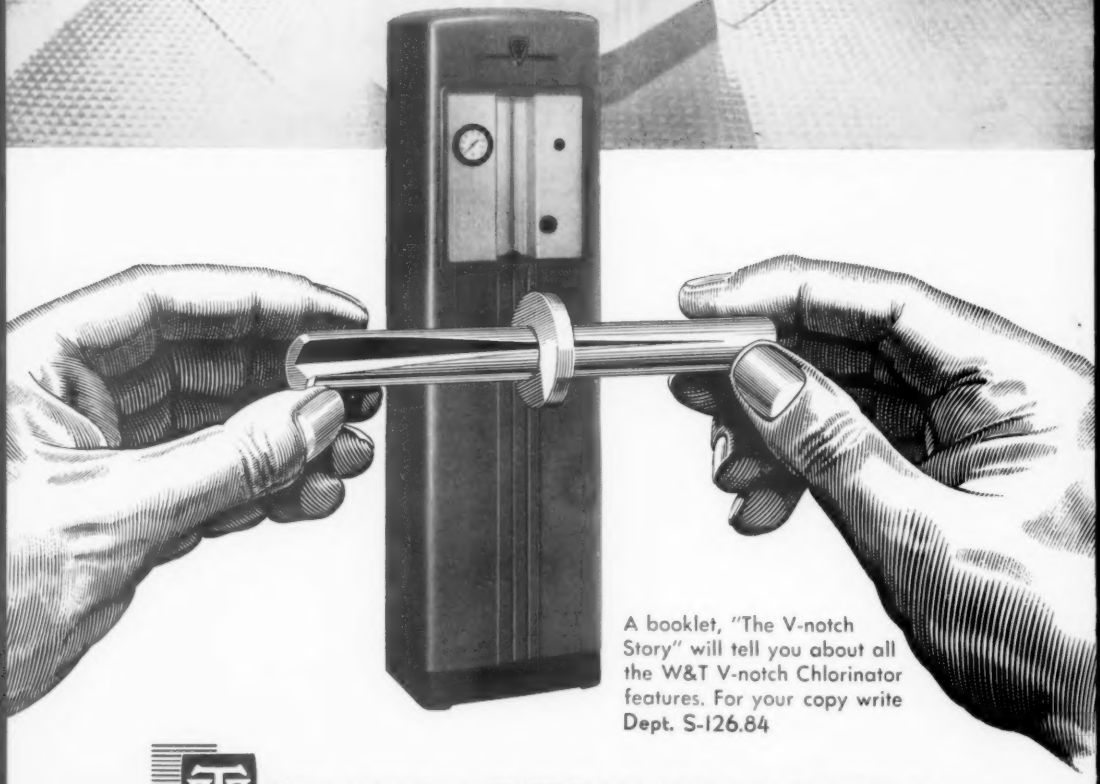

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